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COMPREHENSIVE BASIN STUDY. RED RIVER BELOW DENISON DAM, ARKANSA--ETC(U)

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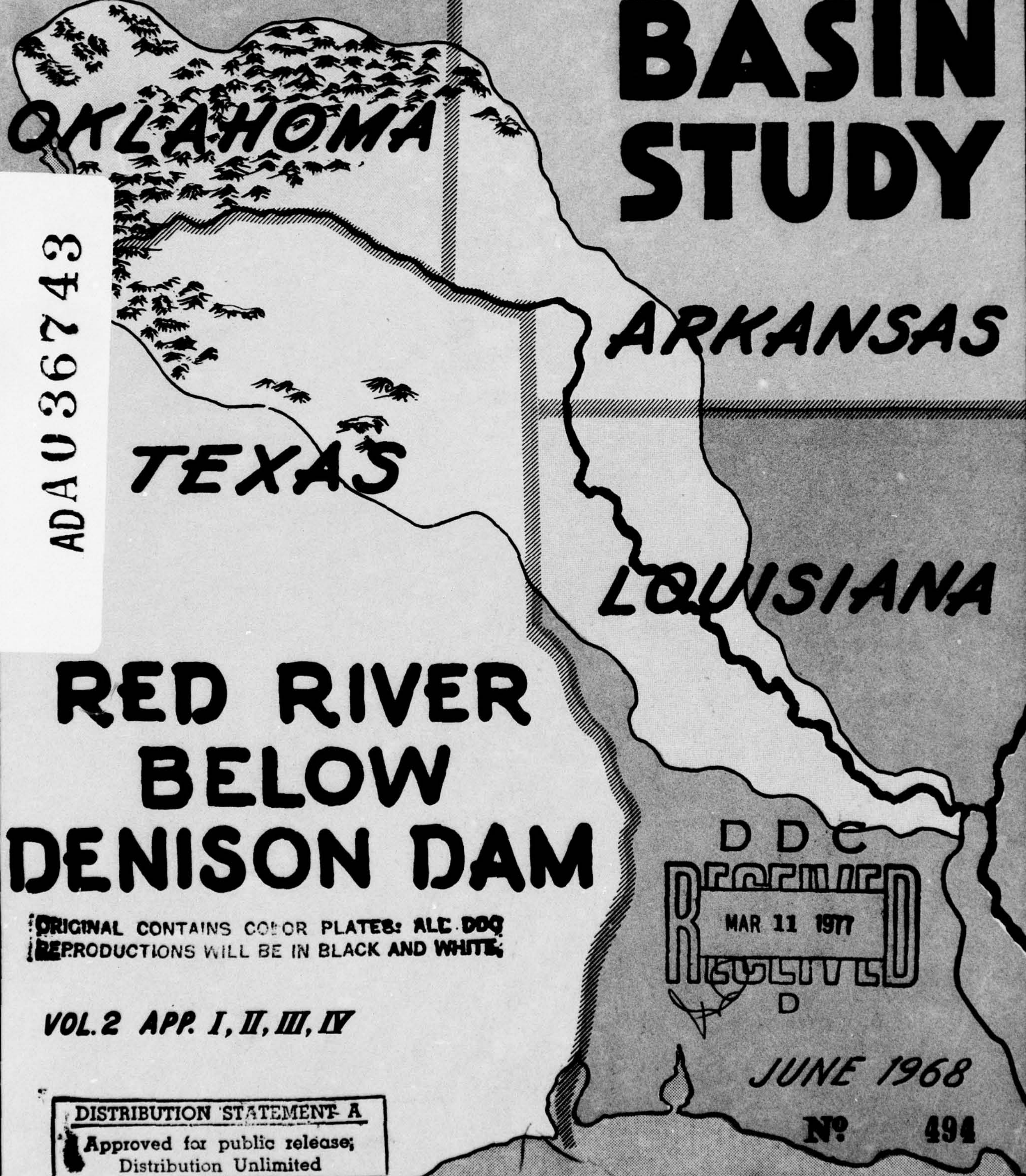
COMPREHENSIVE BASIN STUDY



RED RIVER BELOW DENISON DAM

ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE.

VOL. 2 APP. I, II, III, IV

JUNE 1968

Nº 494

RED RIVER BELOW DENISON DAM
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS
COMPREHENSIVE BASIN STUDY

VOLUME INDEX

(6) Comprehensive Basin Study.

RED RIVER BELOW DENISON DAM,
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS.
~~COMPREHENSIVE BASIN STUDY~~

Volume 2.

Appendices I, II, III and IV.

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APPENDIX I

ECONOMICS

ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE.

Prepared by
U. S. Army Corps of Engineers

June 1968

410089

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ECONOMICS

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APPENDIX I

ECONOMICS

CHAPTER I - INTRODUCTION

1. PURPOSE AND SCOPE

The projects proposed for construction in the interagency report would serve various needs, among which are the development of flood control, navigation, water supply, water quality control, irrigation, hydroelectric power, drainage, land reclamation, recreation, and fish and wildlife, and in serving these needs would produce corresponding benefits. Other benefits not specifically related to these needs will accrue from expenditures for the construction and operation of the projects.

The purpose of this appendix is to present the economic trends of the area encompassed within the Red River Basin below Denison Dam. The economic indicators used to determine trends within the basin area were population, employed labor force, personal income, value added by manufacture, and value of farm products sold. Historical data for the various indicators were analyzed and fundamental economic trends estimated, and used, in conjunction with detailed estimates of the effects of new economic forces and developments, to outline the economic framework within which the proposed projects will operate over their economic lives.

2. RELATIONSHIP TO OTHER APPENDIXES

This appendix establishes a broad and comprehensive concept of the economic growth of the basin area, with respect to the nation and the four-state region, and forms the framework within which projections of the probable magnitude of economic growth of areas affected by specific projects can be developed and evaluated. Developments of these projects are coordinated and utilized, where applicable, in the other appendixes to the main report.

3. DESCRIPTION OF THE BASIN AREA

For the purpose of this study, the Red River Basin was defined as the drainage area of the Red River from Denison Dam to Old River. This area lies within the four-state region of Arkansas, Louisiana, Oklahoma, and Texas, as shown in figure 1. Economic analyses for the basin area are based on the area delineated by shading on figure 1. The following 61 counties and parishes are included. To facilitate the economic analyses the counties and parishes were treated as whole units. These counties and parishes comprise a total of 47,694 square miles of land area as compared with a total basin area of 29,500 square miles.

a. Arkansas. Columbia, Hempstead, Howard, Lafayette, Little River, Miller, Nevada, Polk, and Sevier.

b. Louisiana. Avoyelles, Bienville, Bossier, Caddo, Catahoula, Claiborne, DeSoto, Evangeline, Grant, Jackson, LaSalle, Lincoln, Natchitoches, Rapides, Red River, Sabine, St. Landry, Vernon, Webster, and Winn.

c. Oklahoma. Atoka, Bryan, Choctaw, Coal, Hughes, Johnston, Latimer, LeFlore, McCurtain, Murray, Pittsburg, Pontotoc, and Pushmataha.

d. Texas. Bowie, Camp, Cass, Delta, Fannin, Franklin, Grayson, Gregg, Harrison, Hopkins, Hunt, Lamar, Marion, Morris, Panola, Red River, Titus, Upshur, and Wood.

The Red River Basin, as delineated for this study, lies for the most part in the South Center and Southwest Plains economic region, as defined by Bogue and Beale[1]. Six counties in the southern Oklahoma portion of the basin and two counties in southern Arkansas lie within the Central and Eastern Upland economic region.

The central portion of the basin, consisting of a former heavily forested plain, now second growth pine and pine hardwood forest, is frequently dissected through stream action into rolling topography, and typically endowed with light, sandy leached soils.

The parishes in Louisiana through which the Red River flows consist of broad fertile bottom lands devoted primarily to cotton production. These parishes also have mostly timbered thin soils, often of rolling topography. The Kisatchie National Forest is located in central Louisiana.

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[1] Donald J. Bogue and Calvin L. Beale, Economic Areas of the United States, 1961.

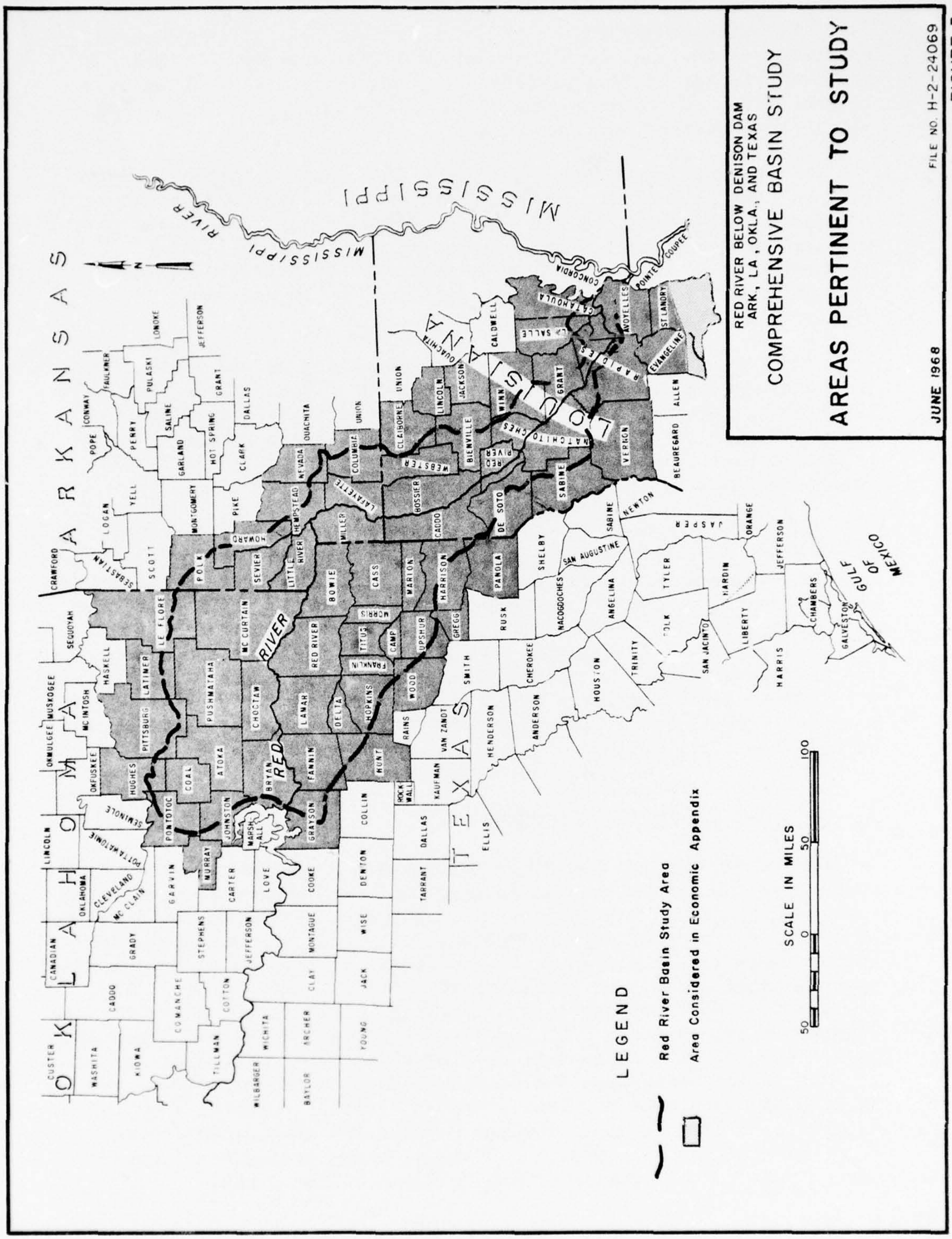
RED RIVER BELOW DENISON DAM
ARK, LA, OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
AREAS PERTINENT TO STUDY
JUNE 1968
FILE NO. H-2-24069
FIGURE I
LEGEND
Red River Basin Study Area
Area Considered in Economic Appendix
SCALE IN MILES
50
0
50
100
OKLAHOMA
ARKANSAS
TEXAS
LOUISIANA
MISSISSIPPI
MISSISSIPPI RIVER
RED RIVER
GULF OF MEXICO

FIGURE I

The Oklahoma portion of the basin ranges from timber covered mountains in the east to the sandstone hills of the west. Most of the western part is open prairie but other parts are occupied by a belt of scrub oak forest. The northeastern part of the area lies within the Ouachita National Forest.

The Arkansas portion of the basin is a land of farming, lumbering, and oil production. Cotton farms are still the most common of the commercial types, but the number of cattle enterprises has grown and broiler farms are now established in all counties. The northern part of the area in Arkansas lies within the Ouachita National Forest. In the southern part, oil is of greater economic significance than lumber.

The Texas portion consists of the blackland on the western edge to the sandy soil in the east. The blackland is a prairie area superior for agriculture while the eastern portion is typified by sandy soils, pine and oak forest cover, small-scale farming, lumber production, and large oilfields. A small section of the Panhandle National Grassland is located in the northwest.

The climate of the Red River Basin varies from moist subhumid in the western portion to humid in the eastern portion. Moderate winters and long summers with relatively high temperatures prevail over the basin. Relative humidity and cloud cover increase from west to the east across the basin area. The normal annual precipitation over the area varies from 35 inches in the western portion to 60 inches in the eastern portion. The basin area is essentially free from severe freezing temperatures which would cause navigation delays. Adequate sunshine prevails which provides a climate favorable to agriculture, as well as to recreational activities and travel.

4. HISTORY OF THE BASIN ECONOMY

A century ago the Red River Basin was a sparsely-inhabited backwoods area. Not one town had as many as 5,000 residents. The areas that were to prove the most desirable for agriculture were undeveloped or nearly so for many decades. Many of the highly productive river bottoms were too poorly drained, too unhealthy and too densely covered with hardwood forests to permit development. After the Civil War, the flood of Southern settlers and foreign immigrants looking for new opportunities, together with the advance of technology and transportation, resulted in a rapid extension of settlement. Thousands of acres of land in the basin were put to the production of cotton. By the turn of the 20th century, some areas had already begun to show the evil effects of soil depletion and erosion and cotton yields felt the impact of the boll weevil. However, these agricultural losses were offset by the opening of the Oklahoma Indian lands.

The discovery of oil, just at the time the automobile was coming into use, brought about the beginning of a more industrialized economy. Beginning around World War I, several towns in the basin started the transformation from an agrarian economy to one based on integrated oil and gas industries and diversified trade and manufactures. Today, although agriculture is still of great importance to the basin's economy, the basin as a whole can no longer be characterized as agricultural, and more workers are engaged in manufacturing, trade, and services than in agriculture.

CHAPTER II - PRESENT ECONOMY

5. INTRODUCTION

The present economy of the Red River Basin is varied. The diverse economy of the area has resulted in a steady growth in manufacturing, value of farm products, and per capita income. The major elements of the economy comprise the petroleum industry, ores and minerals, agriculture, manufacturing and other industries, forest and lumber industry, transportation system, finance and banking, and tourism and recreation. Descriptions of these economic activities in the basin area are presented in the following paragraphs.

6. PETROLEUM INDUSTRY

The Red River Basin contains considerable resources of petroleum. Over 75 percent of all counties and parishes within the basin contain petroleum and natural gas deposits. The accumulations of petroleum in the porous, sedimentary formations usually are associated with natural gas, so that in many oilfields the two commodities are produced together. In addition, natural gas furnishes large amounts of liquid hydrocarbons in the form of condensates, gasoline, and liquified petroleum gases that substantially augment the total reserves.

The demand on the petroleum industry for its products has been moving to a higher level each year. Rising incomes, and increasing industrial activity - not to mention a continued uptrend in travel via both private automobiles and commercial carriers - have all contributed to the ever-greater demand for petroleum products.

7. OTHER MINERALS

In addition to petroleum and natural gas, other mineral commodities produced in the Red River Basin are sand and gravel, coal, iron ore, gypsum, stone, and clays. Sand and gravel, gypsum, stone, and clay exist in large quantities and can be depended upon to exceed basin needs for a period exceeding the life of any water resource projects which are likely to be installed. However, as deposits near urban complexes become depleted, it will be necessary to bring raw materials from greater distances than at present, or move processing plants to the vicinity of new sources of supply. Locally mined iron ore, for example, is being largely replaced by iron pellets from Missouri and Canada as blast furnace fuel. Also, bituminous coal must be brought in to supplement local lignite. In either case, the increasing need for transportation of bulky products and commodities, now extant, will continue.

8. AGRICULTURE

The economic well being of the farmer in the Red River Basin area is constantly improving. The standard of living for farm inhabitants

has shown a progressive upward trend. Improvements have been made in services available to farmers in the form of electric power, telephones, liquified petroleum gases for cooking and heating, and construction of farm-to-market roads. Considerable flood protection is now being afforded to rich valley farm areas throughout the country by various land and water conservation measures. The size of farms is increasing and commercial farms are becoming increasingly important in the agricultural economy.

Over the years, new crops have been introduced and extensive increases in productivity have been accomplished. Important crops now being grown in the basin include cotton, wheat, grain sorghums, oats, rice, rye, corn, soybeans, peanuts, sweet potatoes, barley, and hay. Livestock, poultry and their products are also of considerable importance to the basin's economy.

9. MANUFACTURING AND OTHER INDUSTRIES

The indicators of manufacturing activity such as number of production workers, manufacturing payrolls, value added by manufacture, and the number and size of manufacturing establishments all reflect a relative growth of manufacturing for the Red River Basin and the four-state region, which between 1929 and 1960 was greater than that of the Nation. A steady growth of manufacturing in both the small urban centers and larger metropolitan centers of the basin has diversified income sources and reduced emphasis on agriculture. A large amount of the manufacturing in the basin area is dependent upon raw materials within the four-state area. Most important in this respect are the petroleum and chemical industries which draw heavily upon crude oil and natural gas of the states for basic raw material. Other industries, using the four-state region's raw materials, include iron and steel manufacture, carbon black production, glass, cement, gypsum products, flour mills, dairy plants, other food processors, textiles and apparels, and lumber products and paper. The four-state and basin areas provide markets in varying degrees for crude oil, natural gas, coal, sulfur, salt, gypsum, iron ore, cotton, cottonseed, wheat, grain sorghums, and livestock.

The rate of growth of employment in manufacturing has proceeded at a more rapid pace in the four-state region and the Red River Basin than the United States average during the period 1940-1960. During this period, employment in manufacturing in the United States increased 53 percent or at an average annual rate of increase of 2.2 percent. In the same period, 1940-1960, employment in manufacturing in the four-state region increased 117 percent or at an average annual rate of increase of 4.0 percent. For the Red River Basin, manufacturing employment increased 65 percent from 1940 to 1960, or at an average annual rate of increase of 2.6 percent.

10. FOREST AND LUMBER INDUSTRY

The Red River Basin area includes some of the more heavily timbered portions of the four-state region. Most of the Ouachita National Forest in Oklahoma lies within the basin area. Portions of the Ouachita National Forest (Arkansas) and the Kisatchie National Forest (Louisiana) also lie within the basin. Timber from the National Forests is produced on a sustained yield basis. In addition, there are many privately-owned forest areas in the basin that are managed for sustained yield. Much of this managed forest land is integrated with forest industry.

The basin area contains both softwood and hardwood saw timber. Softwoods are used primarily for lumber, pulp, piles, posts, and poles while the hardwoods are used for lumber, veneer logs, tight cooperage, and handle stock.

Industry relating to forests within the basin area is of considerable importance to the basin's economy. The lumber and wood products industry, furniture and fixtures industry, and the wood pulp and paper industry are prominent in the basin area. Forest areas are customarily associated with rugged topography, scenic beauty, diverse vegetation, lakes, streams, and other natural features, and are thus prime attractions to outdoor recreationists. An increasing demand for recreational use of forest areas is expected.

11. TRANSPORTATION SYSTEM

A dependable transportation network is essential for the economic growth of an area. In this respect, the Red River Basin is favorably located. It is traversed by major railroad systems, transcontinental air routes, a network of national and state highways, and transcontinental bus and truck systems.

a. Railroads. The Red River Basin is served by the Missouri Pacific, Rock Island, St. Louis and Southwestern, Illinois Central, Texas Pacific, Kansas City Southern, and the Louisiana and North West railroads.

b. Air freight. Air freight has been in operation in this area for a number of years and is expanding. It will likely expand until it carries considerable amounts of the small lightweight freight, but nothing so far indicates that it will be a serious competitor for heavy freight items.

c. Motor truck transport. The motor truck industry handles a considerable amount of intercity freight within the basin area. In the year 1963 for the United States as a whole, motor vehicles carried

around 25 percent of the total volume of intercity freight handled by the transportation industry.[1]

d. Pipelines. Pipelines are assuming an ever increasing importance in transportation. At present, they are carrying around one-sixth of the total ton-miles of traffic in the entire nation. They carry nearly all of the crude oil and a large percentage of oil products in the basin area.

e. Water transportation. The Federal project, "Overton-Red River Waterway, La.," was authorized by Public Law 525, 79th Congress, approved 24 July 1946. The authorization provides for construction of a navigation channel 9 feet deep and 100 feet wide from the Mississippi River to Shreveport, La., via the Old and Red Rivers to mile 31 (1930 mileage) on Red River, thence in a land cut generally paralleling the right descending bank of Red River to the vicinity of Shreveport, La. The overall plan lacked public support, however, and on 15 March 1966, a report recommending, inter alia, construction of a 9- by 150-foot navigation channel from the Mississippi River via Old and Red Rivers to Shreveport, La., and thence to Daingerfield, Texas, via Twelvemile and Cypress Bayous, was submitted by the U. S. Army Engineer District, New Orleans. The report, with the recommendation as to channel size changed to 9 by 200 feet, was, as of 1 March 1968, under review by the Bureau of the Budget. Construction of this project would fulfill a pressing need for a water route over which bulk and other commodities may be moved to and from the area.

12. FINANCE AND BANKING

Financial institutions of the Red River Basin, through their ability to control flow of funds, play a leading role in promoting economic development. The four-state region within which the basin lies has experienced substantial gains in bank deposits over the past decade. As reported in the Statistical Abstract of the United States, bank deposits for the four-state region increased from $10.2 billion, or 6.3 percent of national deposits, as of 31 December 1947, to $25.9 billion, or 7.3 percent of the national deposits on 31 December 1964.

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[1] U. S. Bureau of the Census, Statistical Abstract of the United States, 1965.

13. TOURISM AND RECREATION

During the last 25 years the Federal Government has been active in the construction of numerous dams and reservoirs in the Red River Basin area. Similar construction has been accomplished by States, other public entities, and private interests. These projects have given rise to a new and expanding recreational industry of local, regional, and national extent. Denison Dam (Lake Texoma), located on the Red River, had the second largest attendance of all United States reservoirs in 1964 with an attendance of over 8 million visitors. Other important reservoirs in the basin are Bayou Bodcau in Louisiana, Millwood in Arkansas, and Lake O' the Pines and Texarkana in Texas. The rate of expansion of recreational activities associated with water resource development has also increased in the area in which the reservoirs have been constructed. Permanent type resort homes and facilities for winter fishing activities have been established, thus extending the recreational usage period over much of the year.

The impact of recreational areas upon the growth potential of local economies is an important factor in providing an impetus toward a new industrial growth trend, as considerable emphasis is placed on outdoor facilities by industry for recreational activities of employees and their children. Visitor expenditures also have a tremendous influence on the economic growth of an area.

CHAPTER III - ANALYSIS AND SELECTION OF ECONOMIC INDICATORS

14. NATURE OF PROJECTIONS

Economic projections are not predictions but are reasoned estimates of the probable trend of future development. These projections are based primarily on present knowledge of foreseeable developments and relationships of the past. They should not be considered as a prophecy of the future, but rather a forecast of what might occur if a number of specific assumptions regarding the economy of the basin were to occur.

15. STANDARDS USED

Primary importance was placed on national level projections for the principal economic sectors. Use was made of data from United States Government studies published by various agencies and bureaus to determine national, regional, and local trends. For projection purposes, all dollar values were converted to 1960 dollars to make values comparable over varying time periods.

16. ASSUMPTIONS OF GROWTH

Projections of economic growth in the Red River Basin were developed under the following assumptions: (1) No major depressions, wars, or uncontrolled inflation will occur during the projection period; (2) a high level of employment will be maintained; and (3) sufficient water of acceptable quality will be available to support the projected economy.

17. METHOD OF DETERMINING ECONOMIC INDICATORS

The following fields of study were selected for determination of economic indicators of future growth: population, labor force and employment, personal income and per capita income, value added by manufacture, and value of farm products sold. These indicators were selected for the following reasons:

a. Population. All economic growth stems from activities undertaken to satisfy human needs. An industrious population provides the basis for demands for all resources utilized and provides the basic human resource upon which all other economic activities are dependent in varying degrees.

b. Labor force and employment. Labor force and employment are considered an important sector of study because the needs for raw material resources, including water, and basic services, such as power and transportation, stem from man's work-connected activities.

c. Personal and per capita income. Personal income has been selected as an economic indicator since it is the principal component of gross national product (the most comprehensive measure of economic activity), and is the best indicator for which data are available for the basin area.

d. Value added by manufacture. This economic indicator was selected because it is the sole measure of industrial activity available for comparing the relative economic importance of manufacturing among industries and geographical areas.

e. Value of farm products sold. Value of farm products sold is a sensitive indicator of agricultural activity which, in turn, is one of the nation's principal industries.

18. POPULATION

The 1960 population of the four-state region of Arkansas, Louisiana, Oklahoma, and Texas was 9.4 percent of the Nation's total population. The region's share of the national population has fallen slightly during the past 30 years, declining from 9.9 percent in 1930 and 1940 to 9.6 percent in 1950 and to 9.4 percent in 1960. The Red River Basin's share of the Nation's population declined from a high of 1.4 percent in 1940 to a level of 0.9 percent in 1960 (see table 1). The declining share of national population reflects the predominately rural character of the basin's population.

a. Basin area population growth rate. Between 1930 and 1960, the Nation's population rate of growth averaged 1.3 percent compounded annually. The rate of population growth in the four-state region averaged 1.1 percent during the same period. In contrast, the population of the basin area remained almost constant over the 30-year period, showing a net loss of 3,583 people or a loss of 0.02 percent, compounded annually. The net loss of population in the basin area reflects the general decline in rural population which has been taking place throughout the United States.

b. Population growth rate of individual states compared to the continental United States.

(1) Arkansas. The population growth rate for Arkansas during the decade 1900-1910 came close to the national average; 1.9 percent as compared to 2.0 percent for the Nation. Subsequently, the state population, expressed as a percentage of the national population, has declined. Between 1940 and 1960, the total population also declined. The reported 1960 population was 1,786,272, or 1.0 percent of the continental United States population. The long-term population growth rate of the state for the period 1900-1960 has been 0.5 percent annually compared to a rate of 1.5 percent for the continental United States.

(2) Louisiana. The population growth rate for Louisiana has been about the same as the United States for each decade since 1900. In 1960, the population of Louisiana was 3,260,000 or 1.8 percent of the population of the continental United States. This percentage has remained nearly constant since 1900. The long-term growth rate for the state has been the same as that for the continental United States.

TABLE 1

UNITED STATES, FOUR-STATE REGION AND RED RIVER BASIN POPULATION(1)

	1930	1940	1950	1960
Basin Total	1,708,000	1,885,000	1,739,000	1,704,000
U. S. Total	122,775,000	132,594,000	152,271,000	180,684,000
Four-State Total	12,177,000	13,065,000	14,538,000	16,951,000
Basin/U. S.	1.4%	1.4%	1.1%	0.9%
Basin/Four-State	14.0%	14.4%	12.0%	10.1%
Four-State/U/ S.	9.9%	9.9%	9.6%	9.4%

AVERAGE ANNUAL RATE OF CHANGE OF RED RIVER BASIN

1930-1940	1940-1950	1950-1960	1930-1960
1.00%	-0.81%	-0.21%	-0.02%

(1) U. S. Department of Commerce, Bureau of Census, U. S. Census of Population, 1960, 1950, and 1940, Number of Inhabitants.

(3) Oklahoma. Between 1930 and 1950, the State of Oklahoma lost total population; however, in the decade 1950-1960, the population increased to 2,328,284, which was 1.3 percent of the entire continental United States population, and represents a 4.2 percent increase over the 1950 population. The long-term population growth rate of the state for the period 1900-1960 has been 2.0 percent, compared to the continental United States growth rate of 1.5 percent.

(4) Texas. Texas population growth rate has exceeded the national average except for one decade, 1930-1940. Since 1900, the state population has increased at a rate higher than the national average. The reported 1960 population was 9,579,677, or 5.3 percent of the continental United States population. The long-term population growth rate of the state (1900-1960) has been 1.9 percent annually.

c. Urbanization of the basin area. Historically, the population of the basin area has been preponderantly rural. Cities within the area are generally small with only Shreveport and Texarkana having sufficient population (50,000) to be classified as Standard Metropolitan Statistical Areas (SMSA). However, urban areas have been growing at a rapid rate throughout the last 30 years. In 1930, the urban population within the basin area accounted for 21 percent of the total population. By 1960, the urban population made up 47 percent of the total population. For the 30-year period, urban areas enjoyed a 2.8 percent annual rate of growth. Despite this rapid urban growth, the basin area remains less urbanized than either the four-state region or the entire United States.

d. Population change. Table 2 presents the total urban-rural change in population by percent of totals for the Red River Basin, the four-state region, and the United States, for the period 1930-1960. These ratios are approximate, since over a period of time the Census Bureau has changed its definition of what constitutes an urban community.

TABLE 2

RED RIVER BASIN, FOUR-STATE REGION, AND UNITED STATES
POPULATION (% URBAN AND RURAL)(1)

	1930		1940		1950		1960	
	U	R	U	R	U	R	U	R
Red River Basin	21.1	78.9	25.0	75.0	36.6	63.4	47.5	52.5
Four-State Region	33.9	66.1	36.7	63.3	48.3	51.7	57.9	42.1
United States	56.2	43.8	56.5	43.5	64.0	36.0	75.5	24.5

(1) U. S. Department of Commerce, Bureau of Census, U. S. Census of Population, 1960, 1950, and 1940, Number of Inhabitants.

e. Population projections. The historical population figures for the United States are derived from Bureau of Census data published in the Statistical Abstract of the United States, 1965. Population projections for the United States to the year 2020 are based on the Commerce Department's Census of Population, Series B, which projected a rate of population increase of approximately 1.6 percent compounded annually for the 60-year period. This rate was extended to the year 2080 to obtain population estimates for the entire projection period.

It was assumed that the four-state region would maintain its historical share of the national population, approximately 9.6 percent, through the year 2080. This implies that population within the four-state region will grow at the same rate as national population.

On the other hand, because more than half of its population is still in the slow-growing rural areas, the growth of the population of the basin area was projected at a lower rate than that of the nation and four-state region. Consequently, the basin population accounts for a progressively smaller share of the projected national population.

Population projections for each of the four states are based on forecasts made by the U. S. Department of Commerce. The rates projected by the Commerce Department to the year 2000 were extended to 2080 to obtain estimates for years not covered by Commerce Department projections.

Since there was considerable variation among the projected rates of growth for the four states, population projections were made for the portion of each state lying within the basin area. The projections for each portion were based on the overall rate of growth in the state, with upward adjustments in the rate of growth where the character of the portion was more urban than the state as a whole, and vice versa. Because the portions of the basin lying within Louisiana, Texas, and Oklahoma are generally less urbanized than their respective states, they are expected to experience a slower rate of population increase. The Arkansas sector of the basin, on the other hand, is similar in character to the state as a whole, and its population was projected to grow at the same rate as the state. Table 3 and figure 2 show population projections to 2080 for the United States, the four-state region, and the Red River Basin.

In addition to historical trends, the following considerations influenced the choice of projected growth rates. A better balance between the supply of and demand for agricultural products is expected to lead to a stabilization of the absolute size of the rural population at approximately its present levels. This result is based on the assumption that rising population throughout the United States and the world will continue to expand the demand for agricultural products.

The basin area is well provided with natural resources which are expected to attract capital and industry for development. Increased industrialization and resource exploitation is expected to lead to increased urbanization. Past experience shows that "the rates of urbanization were higher in the 'newer' and less developed regions, for the most part, than in the older and more developed areas of the country, though we tend to think of newly settled territory as largely rural."[1] The areas which consistently experienced the most rapid relative growth during the years since 1910 were, on the whole, the least densely populated parts of the country.[2]

Conditions of population saturation and full resource utilization of the east and west coasts will, as time goes on (and our projections extend 100 years into the future), cause industries seeking new locations to find the basin area increasingly attractive. One of the principal requirements for industry is water and the basin area is well-endowed with this resource.

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(1) Harvey S. Perloff, et al, Regions, Resources, and Economic Growth, 1960, page 17.

(2) Ibid, page 11.

TABLE 3

POPULATION: TOTAL, UNITED STATES, FOUR-STATE REGION(1), AND RED RIVER BASIN, 1940, 1950, 1960, AND PROJECTED 1980 TO 2080

Year	United States	Four-State Region(1)	Percent of U. S.	Red River Basin	Percent of U. S.	Red River Basin portion of: Arkansas (2)	Louisiana (3)	Oklahoma (4)	Texas (5)
	Thou.	Thou.	Pct.	Thou.	Pct.	Thou.	Thou.	Thou.	Thou.
1940	132,600	13,064	9.9	1,885.0	1.42	194.8	717.9	364.8	607.5
1950	152,271	14,538	9.6	1,739.0	1.14	166.0	746.0	274.2	552.8
1960	180,676	16,951	9.4	1,704.2	0.94	141.7	824.3	224.3	513.9
1980	245,313	23,476	9.6	2,236.7	0.91	186.1	1,137.9	254.1	658.6
2000	338,219	32,459	9.6	2,948.1	0.87	244.7	1,571.1	287.7	844.6
2020	469,126	45,053	9.6	3,898.1	0.83	321.5	2,168.3	325.8	1,082.5
2040	647,394	62,533	9.6	5,172.7	0.80	422.5	2,993.2	369.1	1,387.9
2060	893,404	85,767	9.6	6,884.9	0.77	555.2	4,131.6	418.2	1,779.9
2080	1,232,900	118,358	9.6	9,188.1	0.74	729.5	5,703.5	473.7	2,281.4

(1) Four-State Region: Arkansas, Louisiana, Oklahoma, Texas

(2) Total population for 9 counties, RRB of Arkansas

(3) Total population for 20 parishes, RRB of Louisiana

(4) Total population for 13 counties, RRB of Oklahoma

(5) Total population for 19 counties, RRB of Texas

Source: Series B, Census of Population, U. S. Department of Commerce; U. S. Corps of Engineers, New Orleans District population projection study by basins (March 1966).

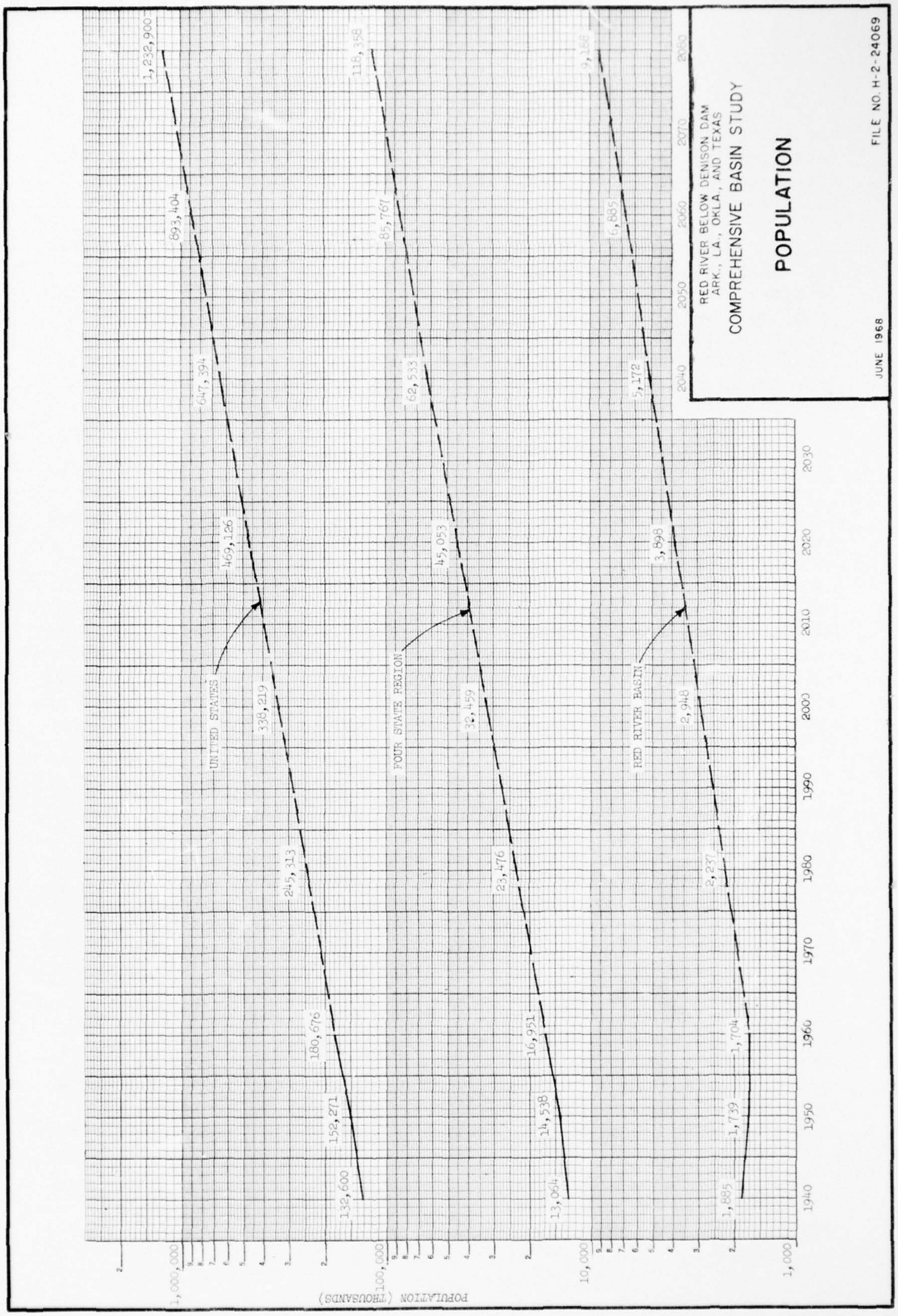
RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
POPULATION
JUNE 1968
FILE NO. H-2-24069
FIGURE 2
POPULATION (THOUSANDS)
UNITED STATES
FOUR STATE REGION
RED RIVER BASIN
132,600
152,271
180,676
249,313
338,219
469,126
647,394
893,404
1,232,900
13,064
14,538
16,951
23,476
32,459
45,053
62,533
85,767
118,358
1,885
1,739
1,704
2,237
2,948
3,898
5,172
6,885
9,168
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080

FIGURE 2

Looking again to the past for indications it may be seen that the population differentiation of the states resulted to a great extent from the spread of a highly productive population and of capital into areas of relatively undeveloped natural resources in response to differential opportunities in various parts of the country.[1]

The basin area, as previously indicated, is well situated in regard to transportation facilities. The readily accessible rail frontage, paved highways, and developed waterways make the basin area practical for both market and resource oriented industry. The recommended navigation channel from the mouth of Red River to Shreveport, Louisiana, and thence to Daingerfield, Texas, will supplement existing transportation media and provide a medium for the low-cost transport of bulk materials.

19. LABOR FORCE AND EMPLOYMENT

a. Classifications. Persons counted as being in the labor force include the employed and the unemployed. The employed category includes (1) those who are at work and (2) those with a job but not at work. Persons in category (1) are defined as those who do any work for pay or profit or who work without pay for 15 hours or more per week on a family farm or business. Category (2) includes persons who have a job from which they are temporarily absent because of vacations, illness, industrial dispute, or bad weather. Unemployed persons actively seeking work are included by the Census Bureau count as among those in the labor force. All civilians 14 years of age or over who are not classified as employed or unemployed are considered as not in the labor force.

b. Basic employment and the multiplier effect. The following discussion is presented to show the relationship between the necessary basic employment and total population. "Basic employment" or that part of a community's total employment which can be identified as serving the outside market exclusively is generated by the demand for goods and services exported and such employment leads to the spending of payrolls in the local market. The "multiplier effect" is the effect of one basic job on the creation of secondary employment in other industries, especially service-type employment. Estimates of multiplier effect vary. However, the Missouri Industrial News reported in February 1962 that the effect of 50 employees in basic industry in a community will result in the support of 300 to 400 people, will require 75 to 100 homes, will put 200 children in school, will require 6 teachers, will cause the purchase of 100 automobiles, will support 10 stores with annual sales of $175,000, will enable 8 professional people (dentists, doctors, lawyers, or ministers)

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[1] Harvey S. Perloff, et al, Regions, Resources, and Economic Growth, 1960, page 9.

to live in the community, will pay about $175,000 annually for transportation, will buy the products from 1,000 acres of land, will provide a monthly payroll of $65,000 to $85,000, and will establish a tax foundation or base of $800,000.

c. Employment data. The changing pattern of employment in the basin area was first examined on the basis of county or parish changes and state total changes in basic industry employment. Employment data for the categories of agriculture, mining, manufacturing, utilities, trade, services, construction, finance (including insurance and real estate), other industries, and not reported, were assembled. Table 4 presents historical labor force and employment data for the basin area within each state. Employment and labor force data were then grouped into the basin area, the four-state region, and the United States totals for comparison and analysis. Table 5 presents these comparative labor force and employment statistics.

d. Agricultural employment. Agricultural employment has experienced a sharp decline in the basin area, the four-state region, and the United States. Employment in agriculture in the basin area decreased from 260,914 in 1940 to approximately 60,089 in 1960, or a 77.0 percent decline. Agricultural employment follows a similar trend for the four-state region, which reported a decrease from 1,407,293 in 1940 to 534,764 in 1960, or 62.0 percent decline. The trend for the United States showed a loss from 8,449,463 in 1940 to 4,256,734 in 1960, or a 49.6 percent decline.

e. Nonagricultural employment. A sharp increase in nonagricultural employment has occurred in the basin area, the four-state region, and the Nation. In the basin area, this has increased from 306,249 in 1940 to 464,841 in 1960, or 51.7 percent, while the four-state region reported an increase from 2,712,589 in 1940 to 5,143,026 in 1960, or 89.6 percent. The nonagricultural employment trend for the United States reported an increase from 36,620,852 in 1940 to 60,382,513 in 1960, or an increase of 64.9 percent.

TABLE 4

EMPLOYMENT AND LABOR FORCE
RED RIVER BASIN
ARKANSAS-LOUISIANA-OKLAHOMA-TEXAS(1)

Industry	Basin Area State of Arkansas			Basin Area State of Louisiana			Basin Area State of Oklahoma			Basin Area State of Texas			Basin Area Four-State Total		
	1940	1950	1960	1940	1950	1960	1940	1950	1960	1940	1950	1960	1940	1950	1960
Agriculture	31,724	16,889	6,179	101,936	55,482	25,358	42,119	26,649	10,041	85,135	47,054	18,511	260,914	146,074	60,089
Mining	750	1,021	1,022	6,712	8,988	7,926	2,521	2,766	2,061	4,900	5,115	4,247	14,883	17,890	15,256
Manufacturing	6,304	9,446	10,932	24,436	28,945	32,827	6,159	6,687	8,386	15,496	21,834	34,460	52,395	66,912	86,605
Utilities, Communications, Trans.	2,080	3,008	2,946	10,201	15,127	18,559	3,119	4,511	3,600	9,514	13,973	11,924	24,914	36,619	37,029
Trade	5,635	7,981	8,066	27,418	39,730	46,913	10,847	12,896	13,343	24,774	34,566	33,207	68,674	95,173	101,529
Services	7,727	8,222	9,712	45,294	47,927	68,505	13,308	13,343	14,377	31,594	35,424	38,985	97,923	104,916	131,579
Construction	1,610	2,940	2,851	8,644	16,462	19,944	2,558	4,708	5,074	7,496	12,562	12,647	20,308	36,672	40,516
Finance, Insurance, Real Estate	511	684	1,017	2,916	4,383	7,408	1,022	1,188	1,411	2,803	3,770	4,914	7,252	10,025	14,750
Other Industries - Not Reported	5,359	1,155	1,091	12,049	4,905	6,834	15,607	1,571	1,645	17,356	2,807	5,880	50,371	10,438	15,450
Government	904	1,998	1,676	7,038	7,461	10,037	2,235	3,913	3,619	3,702	9,992	6,795	13,879	23,364	22,127
Armed Forces	N.A.	56	153	N.A.	6,267	10,325	N.A.	177	222	N.A.	2,562	2,613	N.A.	9,062	13,313
Total Employed Labor Force	N.A.	53,400	45,645	N.A.	235,677	254,636	N.A.	78,409	63,779	N.A.	189,659	174,183	N.A.	557,145	538,243
Total Population	194,819	165,955	141,703	717,872	746,000	824,307	364,807	274,237	224,302	607,522	552,774	513,865	1,885,020	1,738,966	1,704,177
Population/14 years and over	137,321	116,759	101,526	506,560	514,727	554,570	253,047	194,082	165,097	442,610	401,490	371,898	1,339,538	1,227,058	1,193,091
Labor Force	N.A.	55,574	48,848	N.A.	243,716	270,453	N.A.	82,032	68,272	N.A.	197,398	182,278	N.A.	578,720	569,851
Civilian Labor Force	66,652	55,518	48,695	261,540	237,449	260,128	112,202	81,855	68,050	218,285	194,836	179,665	658,679	569,658	556,538
Employed Civilian Labor Force	62,604	53,344	45,492	246,644	229,410	244,311	99,495	78,232	63,557	202,770	187,097	171,570	611,513	548,083	524,930
Unemployed Civilian Labor Force	4,048	2,174	3,203	14,896	8,039	15,817	12,707	3,623	4,493	15,515	7,739	8,095	47,166	21,575	31,608

(1)U. S. Department of Commerce, Bureau of the Census, U. S. Census of Population, 1960, 1950, and 1940, General Social and Economic Characteristics.

TABLE 5

EMPLOYMENT AND LABOR FORCE
THE UNITED STATES, FOUR-STATE REGION AND RED RIVER BASIN(1)

Industry	The United States 1940	1950	1960	Four-State Region 1940	1950	1960	Red River Basin 1940	1950	1960	Percent Four-State is of United States 1950	1960	Percent Basin is of United States 1950	1960	Percent Basin is of Four States 1950	1960
Agriculture	9,540,000	7,497,000	5,723,000	1,407,293	962,669	534,764	260,914	146,074	60,089	12.8	9.3	1.9	1.0	15.2	11.2
Mining	925,000	901,000	712,000	117,142	161,686	176,508	14,883	17,890	15,256	17.9	24.8	2.0	2.1	11.1	8.6
Manufacturing	10,985,000	15,241,000	16,791,000	420,807	667,308	915,038	52,395	66,912	86,605	4.4	5.4	0.4	0.5	10.0	9.5
Utilities, Communications, Trans.	3,038,000	4,034,000	4,004,000	249,098	396,329	424,319	24,914	36,619	37,029	9.8	10.6	0.9	0.9	9.2	8.7
Trade	6,759,000	9,386,000	11,391,000	670,936	1,007,265	1,173,562	68,674	95,173	101,529	10.7	10.3	1.0	0.9	9.4	8.7
Services	3,681,000	5,382,000	7,392,000	902,163	1,135,880	1,579,853	97,923	104,916	131,579	21.1	21.4	1.9	1.8	9.2	8.3
Construction	1,294,000	2,333,000	2,885,000	190,824	395,789	426,080	20,308	36,672	40,516	17.0	14.8	1.6	1.4	9.3	9.5
Finance, Insurance and Real Estate	1,502,000	1,919,000	2,669,000	95,576	142,974	218,764	7,252	10,025	14,750	7.5	8.2	0.5	0.6	7.0	6.7
Other - Not Reported	5,603,000	7,031,000	6,594,000	66,043	133,411	228,902	50,371(2)	10,438	15,450	1.9	3.5	0.1	0.2	7.8	6.7
Government	4,202,000	6,026,000	8,520,000	276,542	504,485	647,965	13,879	23,364	22,127	8.4	7.6	0.4	0.3	4.6	3.4
Armed Forces	540,000	1,650,000	2,514,000	35,500	127,703	221,817	N.A.	9,062	13,313	7.7	8.8	0.5	0.5	7.1	6.0
Total Employed Labor Force	48,069,000	61,400,000	69,195,000	4,431,924	5,635,519	6,547,572	N.A.	557,145	538,243	9.2	9.5	0.9	0.8	9.9	8.2
Total Population	132,600,000	152,200,000	180,700,000	13,064,525	14,537,572	16,951,225	1,885,020	1,738,966	1,704,177	9.6	9.4	1.1	0.9	12.0	10.1
Population/14 Years and Over	100,380,000	110,929,000	125,368,000	9,547,782	10,432,053	11,645,130	1,339,538	1,227,058	1,193,091	9.4	9.3	1.1	1.0	11.8	10.2
Labor Force	56,189,000	64,751,000	73,126,000	5,102,271	5,849,842	6,840,005	N.A.	578,720	569,851	8.9	9.4	0.9	0.8	9.9	8.3
Civilian Labor Force	55,649,000	63,101,000	70,612,000	5,066,771	5,722,139	6,618,188	658,679	569,658	556,538	9.1	9.4	0.9	0.8	10.0	8.4
Employed Civilian Labor Force	47,529,000	59,750,000	66,681,000	4,396,424	5,507,816	6,325,755	611,513	548,083	524,930	9.2	9.5	0.9	0.8	10.0	8.3
Unemployed Civilian Labor Force	8,120,000	3,351,000	3,931,000	670,347	214,323	292,433	47,166	21,575	31,608	6.4	7.4	0.6	0.8	10.1	10.8

(1) U. S. Department of Commerce, Bureau of the Census, U. S. Census of Population, 1960, 1950, and 1940, General, Social, and Economic Characteristics.

(2) Includes 44,350 for Public Works.

f. Employment changes. An analysis of the employment changes after adjustment for agricultural losses in jobs from 1940 to 1960 discloses the following:

Employment area	Nonagricultural gain 1940-1960	Loss in agriculture 1940-1960	Net change 1940-1960
Basin area	158,596	200,825	-42,229
Four-state region	2,430,437	872,529	1,557,908
United States	23,761,661	4,192,729	19,568,932

This comparison reveals the great historical dependence on agricultural activities and the high transfer rate from agrarian pursuits to non-agricultural activities, in the basin area, the four-state region, and the Nation. The basin area had an agricultural employment decline rate of 7.5 percent in the period 1940-1960, compared to 5.0 percent for the four-state region and 3.5 percent for the United States.

g. Productivity. Productivity relates output to input. For the purpose of this study, productivity is defined as the ratio of real product to man-hours of work put into the product. It may increase, become stable, or decrease during any given period. Productivity may be increased by such factors as research, capital investment, technological and managerial advancement, and advancement of education. Many factors are at work which restriain productivity, including scarcity of skilled labor and management, increasing real costs of resources such as water, increasing real costs of distribution, and insufficient public facilities, such as transportation. An inevitable cause and effect relationship exists between the level of labor productivity and the level of real income of wage and salary workers across the Nation in general and on a national basis. For example, the gross national product of the Nation was, in 1947, produced by 62 million workers in the labor force, and had a value, in constant 1957 dollars, of $305 billion. In 1957, in dollars of the same value, the gross national product of the Nation was $440 billion produced by 68 million members of the labor force, or a 13 percent increase in employment, and a 44 percent increase in the produce for national consumption. The difference between the 13 percent and 44 percent is a measure of the gain in physical production per worker which can be distributed in one way or another in the form of higher wages, or higher salaries, lower prices, greater profits (to management and stockholders), or a combination of these forms. The increase in national labor productivity over the past years has averaged 2 and 3 percent per year, with sizable year to year variations. Future changes in productivity are of considerable concern to the Nation. In the past, the stimulating factors have always outweighed the

restraining factors, and under our free enterprise economic system, likely will continue to do so for the foreseeable future.

h. Projected labor force and employment. Historically, the labor force in both the four-state region and the basin area has accounted for a smaller fraction of the total population than has the national labor force. This lower labor force participation rate in the basin area is explained largely by the lower participation rates of females in rural areas and by the out migration of individuals of working age who sought employment off the farms. With increasing urbanization and a stabilization of agricultural employment opportunities, the labor force participation rates in the basin area are expected to gradually approach the national levels. Table 6 presents projected employment for the years 1980, 2000, 2020, 2040, 2060, and 2080 for the United States, the four-state region, and the Red River Basin.

20. PERSONAL INCOME

a. Personal and per capita income growth. Personal income growth in the United States was slightly greater than personal income growth in the Red River Basin and lower than the personal income growth in the four-state region during the years 1930-1964. These rates of growth for the United States, the four-state region, and the Red River Basin were 3.7 percent, 4.6 percent, and 3.5 percent, respectively.

Per capita income growth in the United States was lower than the per capita income growth in both the four-state region and Red River Basin area during the period 1930-1960. These rates of growth for the United States, four-state region, and Red River Basin were 2.3 percent, 3.4 percent, and 3.5 percent, respectively. Table 7 presents personal income and per capita income data in 1960 dollars for the areas mentioned above. These 1960 dollar figures were derived by the use of the consumer price index. Table 7 also presents average annual growth rates for selected intervals.

b. Growth of personal income by major industry category and other sources. Using the income data broken down into type and source, answers can be developed to some of the questions which are constantly arising concerning changes in the importance of the various industry groups and in the four major categories of income source which are involved in the economic base of each state. The following sources of income growth were compared for the four-state region, the individual states comprising the four-state region, and the Nation:

TABLE 6

PROJECTED EMPLOYMENT
THE UNITED STATES, FOUR-STATE REGION, AND RED RIVER BASIN
(in thousands)

Industry	UNITED STATES(1) 1980	2000	2020	2040	2060	2080	FOUR-STATE REGION 1980	2000	2020	2040	2060	2080	RED RIVER BASIN(2) 1980	2000	2020	2040	2060	2080
Agriculture	3,277	2,329	2,072	2,500	3,000	3,500	292	255	240	268	318	384	55	50	50	52	53	55
Mining	648	606	560	784	1,097	1,532	163	142	136	117	97	87	22	30	37	50	69	95
Manufacturing	23,000	29,034	37,473	52,490	73,400	102,529	1,413	2,068	2,963	4,247	5,998	8,440	128	183	255	355	483	661
Utilities, Communications, Trans.	4,568	5,781	7,920	11,094	15,513	21,670	628	871	1,185	1,651	2,310	3,228	51	66	84	113	155	214
Trade	16,927	26,094	39,163	54,858	76,711	107,153	1,710	2,381	3,323	4,675	6,527	9,156	142	200	269	369	506	696
Services	14,571	24,120	37,678	52,777	73,802	103,090	2,242	3,143	4,400	6,201	8,681	12,187	188	262	354	485	669	924
Construction	7,066	9,924	12,195	17,082	23,887	33,367	694	1,003	1,420	2,025	2,877	4,083	56	74	99	135	185	254
Finance, Insurance and Real Estate	4,689	7,548	11,386	15,949	22,303	31,153	339	496	715	1,033	1,474	2,099	22	32	45	63	86	119
Other - Not Reported	7,334	10,279	13,861	19,416	27,150	37,925	388	604	881	1,273	1,823	2,609	18	25	32	44	60	82
Government	10,508	14,434	20,100	28,155	39,371	54,995	1,029	1,523	2,193	3,135	4,234	5,972	30	41	55	75	102	140
Armed Forces	3,470	3,470	3,470	3,470	3,470	3,470	228	208	203	198	193	192	18	18	18	18	18	18
Total Employed	96,058	133,619	185,878	258,575	359,704	500,384	9,126	12,694	17,658	24,823	34,532	48,037	730	981	1,298	1,759	2,386	3,258
Total Population	245,313	338,219	469,126	647,394	893,404	1,232,900	23,476	32,459	45,053	62,533	85,767	118,358	2,237	2,948	3,898	5,173	6,885	9,188

(1)Department of the Army, SWD, Corps of Engineers, "National Economic Growth Projections, 1980-2020," 18 February 1966.

(2)Department of the Army, NOD, Corps of Engineers.

TABLE 7

TOTAL PERSONAL AND PER CAPITA INCOME

Total Personal Income (Millions of 1960 Dollars)

	1930	% Change 1930-1940	1940	% Change 1940-1950	1950	% Change 1950-1960	1960	% Change 1960-1964	1964	% Change 1930-1964
United States(1)	136,000	2.0	167,000	5.3	281,000	3.6	401,000	4.1	471,000	3.7
Four-State Region(1)	7,887	2.9	10,561	7.3	21,376	3.6	30,425	4.6	36,500	4.6
Red River Basin Area(2)	841	2.8	1,103	5.6	1,908	2.1	2,355	4.1	2,758	3.5

Per Capita Personal Income (1960 Dollars)

	1930	% Change 1930-1940	1940	% Change 1940-1950	1950	% Change 1950-1960	1960	% Change 1930-1960
United States(1)	1,107	1.3	1,259	3.9	1,845	1.9	2,219	2.3
Four-State Region(1)	648	2.2	808	6.1	1,470	2.0	1,795	3.4
Red River Basin Area(2)	492	1.8	585	6.5	1,097	2.3	1,381	3.5

(1) U. S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States.

(2) Sales Management Magazine, 1930-1965.

(1) Farm income. The increase in farm income in the four-state region for the period 1929-1964 was 54 percent as compared to the Nation's increase of 19 percent. However, during the period, Oklahoma reported a decline of 131 percent, while Texas, Arkansas, and Louisiana reported increases of 73, 218, and 62 percent, respectively. The farm income growth in the four-state region for the same period was 1.25 percent compounded annually, compared to an 0.50 percent increase for the Nation.

	Percent of income derived from farming		Percent change in farm income
	1929	1964	1929 - 1964
United States	1.5	0.6	+19
Four-state region	2.7	1.1	+54
Arkansas	2.1	2.2	+218
Louisiana	1.8	0.7	+62
Oklahoma	3.1	0.5	-131
Texas	2.9	1.1	+73

(2) Mining income. Income derived from mining in the four-state region increased 240 percent during the period 1929-1964 compared to the Nation's increase of 44 percent. The states of Louisiana and Texas accounted for nearly all of the increase. The income growth rate of the mining sector for the four-state region was 3.60 percent compounded annually compared to 1.06 percent for the Nation.

	Percent of income derived from mining		Percent change in mining income
	1929	1964	1929 - 1964
United States	1.8	0.8	+44
Four-state region	4.1	3.5	+240
Arkansas	2.1	0.8	+9
Louisiana	1.2	4.7	+1,583
Oklahoma	11.1	5.3	+26
Texas	2.7	3.2	+446

(3) Contract construction income. Contract construction income in the four-state region increased 581 percent for the period 1929-1964 compared to the Nation's increase of 333 percent. All of the states in the four-state region with the exception of Oklahoma showed strong percentage increases, exceeding the national percentage increase. The contract construction income growth rate for the

four-state region was 5.70 percent compounded annually compared to 4.30 percent for the Nation.

	Percent of income derived from contract construction		Percent change in construction income
	1929	1964	1929 - 1964
United States	2.9	4.0	+333
Four-state region	2.5	4.2	+581
Arkansas	1.9	3.8	+515
Louisiana	1.6	5.1	+1,236
Oklahoma	2.3	3.6	+313
Texas	2.9	4.2	+565

(4) Manufacturing income. The manufacturing income in the four-state region increased 508 percent during the period 1929-1964 compared to the Nation's increase of 259 percent. All of the states exceeded the national percentage increase for the period 1929-1964. The manufacturing income growth rate for the four-state region was 5.30 percent compounded annually, compared to 3.70 percent for the Nation.

	Percent of income derived from manufacturing		Percent change in manufacturing income
	1929	1964	1929 - 1964
United States	18.8	21.3	+259
Four-state region	8.6	13.2	+508
Arkansas	8.7	15.8	+467
Louisiana	13.4	13.4	+314
Oklahoma	6.6	10.1	+301
Texas	7.8	13.5	+687

(5) Wholesale and retail trade income. The income derived from wholesale and retail trade in the four-state region increased 354 percent during the period 1929-1964 compared to the Nation's increase of 254 percent. Arkansas and Oklahoma fell below the national percentage increase while Louisiana and Texas exceeded it. The income growth rate for this category for the four-state region was 4.40 percent compounded annually, compared to 3.70 percent for the Nation.

	Percent of income derived from wholesale and retail trade		Percent change in wholesale and retail trade
	1929	1964	1929 - 1964
United States	10.9	12.2	+254
Four-state region	10.9	12.6	+354
Arkansas	9.2	10.3	+252
Louisiana	9.9	12.2	+409
Oklahoma	11.1	11.7	+177
Texas	11.5	13.2	+422

(6) Finance, real estate, and insurance income. The income derived from finance, real estate, and insurance in the four-state region increased 364 percent during the period 1929-1964 compared to the Nation's increase of 204 percent. Only Oklahoma failed to exceed the national percentage increase. The income growth rate for this category for the four-state region was 4.50 percent compounded annually compared to 3.25 percent for the Nation.

	Percent of income derived from finance, insurance and real estate		Percent change in finance, insurance and real estate income
	1929	1964	1929 - 1964
United States	3.4	3.3	+204
Four-state region	2.6	3.0	+364
Arkansas	2.1	2.3	+232
Louisiana	3.0	2.9	+300
Oklahoma	2.5	2.8	+194
Texas	2.5	3.2	+473

(7) Transportation industry income. The income from the transportation industry in the four-state region increased 119 percent during the period 1929-1964 compared to the United States increase of 91 percent. Louisiana and Texas exceeded the national percentage increase, while Arkansas and Oklahoma fell below it. The income growth rate for this category for the four-state region was 2.25 percent compounded annually compared to 1.87 percent for the Nation.

	Percent of income derived from transportation		Percent change in transportation income
	1929	1964	1929 - 1964
United States	5.5	3.3	+91
Four-state region	6.7	3.9	+119
Arkansas	6.7	3.4	+59
Louisiana	8.0	4.3	+124
Oklahoma	4.8	3.4	+85
Texas	7.1	4.0	+156

(8) Communications and public utilities income. Communications and public utilities income in the four-state region increased 427 percent during the period 1929-1960 compared to the Nation's increase of 256 percent. All states exceeded the national percentage increase in income. The income growth rate for the four-state region was 4.85 percent compounded annually, compared to 3.70 percent for the Nation.

	Percent of income derived from communications and public utilities		Percent change in communications and public utilities income
	1929	1964	1929 - 1964
United States	1.8	2.0	+256
Four-state region	1.6	2.2	+427
Arkansas	1.1	2.0	+491
Louisiana	1.5	2.3	+533
Oklahoma	1.6	2.2	+258
Texas	1.8	2.2	+443

(9) Services industry income. Services-derived income in the four-state region increased 372 percent during the period 1929-1964 compared to the Nation's increase of 275 percent. Louisiana and Texas exceeded the national percentage increase in income. The income growth rate for the services industry for the four-state region was 4.55 percent compounded annually to 3.87 percent for the Nation.

	Percent of income derived from services		Percent change in service industry income
	1929	1964	1929 - 1964
United States	6.4	7.6	+275
Four-state region	5.9	7.0	+372
Arkansas	5.0	5.6	+253
Louisiana	8.1	7.7	+295
Oklahoma	4.7	6.5	+269
Texas	5.8	7.1	+456

(10) Government employment income. Income derived from Government employment in the four-state region increased 858 percent during the period 1929-1964 compared to the national increase of 601 percent. All the states of the four-state region exceeded the national percentage increase. The income growth rate for the Government sector for the four-state region was 6.60 percent annually compared to 5.75 percent for the Nation.

	Percent of income derived from Government employment		Percent change in Government employment income
	1929	1964	1929 - 1964
United States	5.6	12.5	+601
Four-state region	5.8	14.1	+858
Arkansas	5.1	11.8	+609
Louisiana	6.7	13.4	+730
Oklahoma	5.5	16.3	+683
Texas	5.8	14.2	+1,011

(11) Other industries income. Income derived from other industries in the four-state region did not increase by as great a percentage as the Nation during the period 1929-1964, the region increasing only 214 percent as compared to the national increase of 244 percent. The states of Texas and Louisiana exceeded the national percentage increase. The income growth rate for the "Other Industries" sector for the four-state region was 3.30 percent compounded annually compared to 3.60 percent for the Nation.

	Percent of income derived from other industries		Percent change in other industries income
	1929	1964	1929 - 1964
United States	0.1	0.2	+244
Four-state region	0.2	0.2	+214
Arkansas	0.4	0.3	+100
Louisiana	0.2	0.2	+275
Oklahoma	0.4	0.2	+29
Texas	0.2	0.2	+429

(12) Other labor income. Income derived from other labor in the four-state region increased 1663 percent during the period 1929-1964 compared to the Nation's increase of 1288 percent. Arkansas, Louisiana, and Texas exceeded the national percentage increase for the period. The income growth rate for the other labor sector for the four-state region was 8.50 percent compounded annually compared to 7.75 percent for the Nation.

	Percent of income derived from other labor		Percent change in other labor income
	1929	1964	1929 - 1964
United States	0.7	2.9	+1,288
Four-state region	0.6	2.9	+1,663
Arkansas	0.4	2.5	+1,900
Louisiana	0.7	3.1	+1,745
Oklahoma	0.6	2.7	+977
Texas	0.7	3.0	+1,871

(13) Proprietor's income. Income derived from proprietorship in the four-state region increased 83 percent during the period 1929-1964 compared to the national increase of 91 percent. Only Texas exceeded the national percentage increase. The income growth rate for the proprietorship sector for the four-state region was 1.75 percent compounded annually, compared to 1.87 percent for the Nation.

	Percent of income derived from proprietorship		Percent change in proprietorship income
	1929	1964	1929 - 1964
United States	17.2	10.4	+91
Four-state region	29.3	13.5	+83
Arkansas	40.1	20.4	+59
Louisiana	25.4	11.5	+88
Oklahoma	27.3	14.8	+42
Texas	29.0	12.9	+103

(14) Property income. Income derived from property management in the four-state region increased 208 percent during the period 1929-1964 compared to the Nation's increase of 102 percent. All of the states in the four-state region exceeded the national percentage increase for the period 1929-1964. The income growth rate for the property management sector for the four-state region was 3.25 percent compounded annually compared to 2.05 percent for the Nation during the period 1929-1964.

	Percent of income derived from property management		Percent change in property income
	1929	1964	1929 - 1964
United States	21.8	13.9	+102
Four-state region	16.8	13.2	+208
Arkansas	12.2	10.8	+175
Louisiana	17.0	12.0	+194
Oklahoma	16.8	13.1	+104
Texas	17.8	13.8	+256

c. Projected total personal income and per capita income. Table 8 presents the historical and projected total personal income and per capita income for the United States, the four-state region, and the Red River Basin. Projected personal income for the United States to the year 2020 was furnished by the Southwestern Division, Corps of Engineers. The figures for the years 2040 to 2080 were obtained by extending the 1960-2020 data at a slightly reduced rate of growth. Projected personal income for the four-state region and the basin area was derived by projecting historical trends. Historical and projected relationships among the Red River Basin, the four-state region, and the United States were analyzed and adjustments made after comparison with population, employment, and per capita income, where

TABLE 8

HISTORICAL(1) AND PROJECTED(2) PERSONAL AND PER CAPITA INCOME

Total Personal Income (Millions of 1960 Dollars)

	1940	1950	1960	1980	2000	2020	2040	2060	2080
United States	167,000	281,000	401,000	864,000	1,863,000	4,010,000	8,373,000	16,666,000	33,162,000
Four-State Region	10,561	21,376	30,425	66,813	153,109	334,834	735,451	1,527,339	3,069,496
Red River Basin Area	1,103	1,908	2,355	5,110	10,830	23,140	49,500	105,880	226,480

Per Capita Income (1960 Dollars)

	1940	1950	1960	1980	2000	2020	2040	2060	2080
United States	1,259	1,845	2,219	3,522	5,508	8,548	12,933	18,654	26,898
Four-State Region	808	1,470	1,795	2,846	4,717	7,432	11,761	17,808	25,934
Red River Basin Area	585	1,097	1,381	2,285	3,674	5,936	9,569	15,378	24,649

(1) U. S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States and Sales Management Magazine.
(2) Department of the Army, SWD Corps of Engineers and NOD Corps of Engineers.

necessary for proper balance. Projected Personal Income is shown in figure 3, and Projected Per Capita Income is shown in figure 4.

21. VALUE ADDED BY MANUFACTURE

a. Historical values. Value added by manufacture is the best measure available for comparing the relative economic importance of manufacturing by industries and by geographic areas. Value added by manufacture was taken from U. S. Bureau of the Census reports. The data in these reports were derived by taking the value of shipments for products manufactured and subtracting the costs of materials, supplies and containers, fuel, purchased electric energy, and contract work and adding receipts for services rendered. These figures were then adjusted by taking into account the following factors: (1) value added by merchandising operations (that is, the difference between the sales value and cost of merchandise sold without further manufacture, processing or assembly), plus (2) the net change in finished goods and work-in-process inventories between the beginning and end of the year. Under this concept, the objective is the measurement of all activities of all establishments defined as primarily manufacturing. This important measure of industrial activity is extremely useful as various industry groups (petroleum and coal products, textiles, mill products) can be analyzed in terms of value added. Manufacturing is the largest of the industrial sectors of the economy, sharing 28.3 percent of the total national income in 1958 in current dollars. By 1963, this share increased to 28.8 percent. In the year 1929, the manufacturing share of the national income was 24.9 percent; in 1939, 24.6 percent; in 1947, 29.6 percent; and in 1954, 31.2 percent.

b. Manufacturing census. The census of manufacturing (U. S. Department of Commerce) is enumerated every 4 years in detail, the last census having been taken in 1963. Table 9 presents the "Value added by manufacture" for the United States, the four-state region, and the Red River Basin for the period 1929-1963. The average annual percent change is also shown.

c. Historical growth. The basin area has increased or maintained its share of the national total value added by manufacture in each of the years reviewed since 1939. In the four-state region, however, value added by manufacture has, with the exception of the 1963 data, in which the basin area has shown a greater growth rate, grown more rapidly than either the basin area or the United States. Consequently, the basin area has accounted for a progressively smaller share of the four-state total until the year 1963.

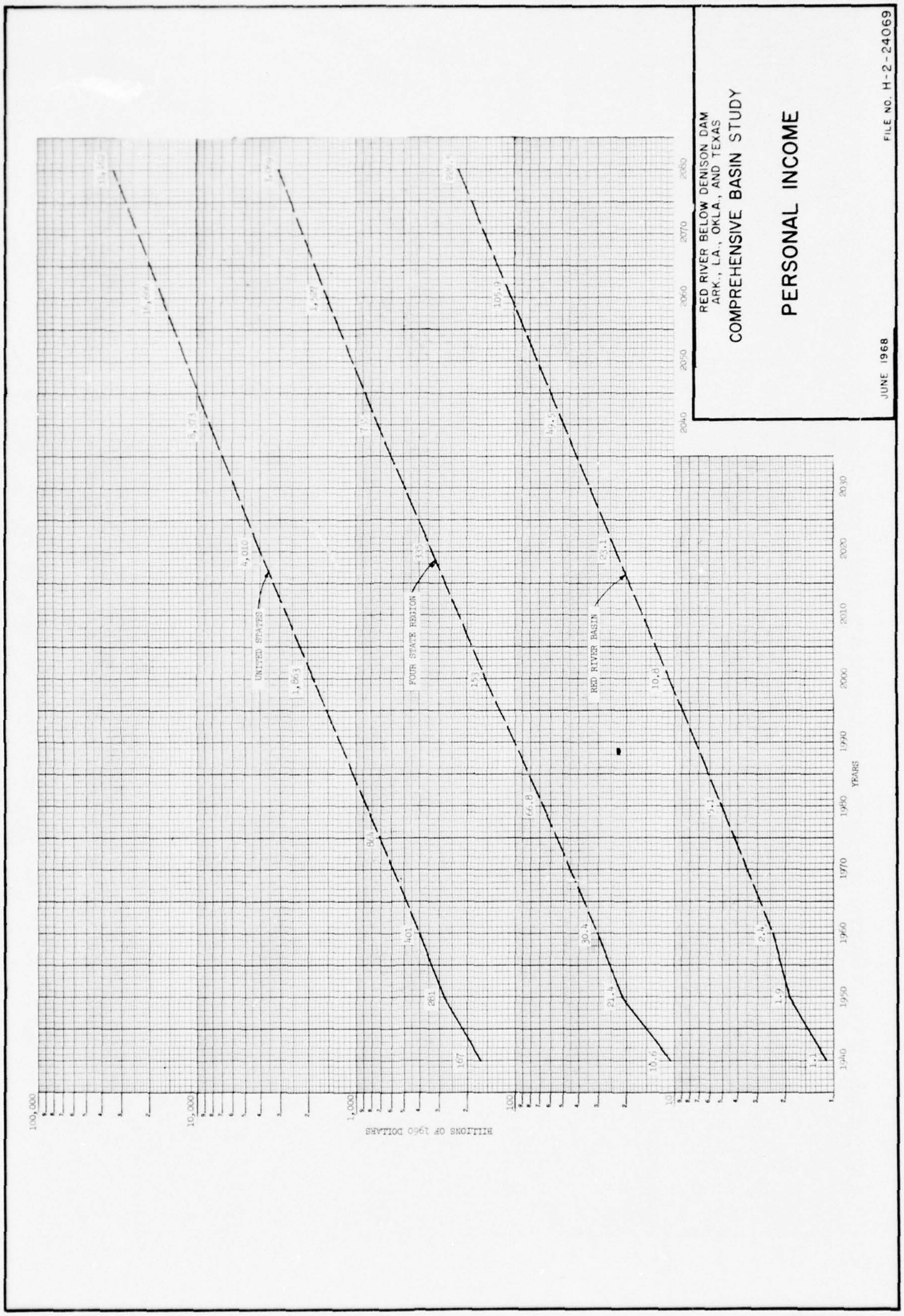

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
PERSONAL INCOME
JUNE 1968
FILE NO. H-2-24069
FIGURE 3
UNITED STATES
FOUR STATE REGION
RED RIVER BASIN
BILLIONS OF 1960 DOLLARS
YEARS
167
281
401
804
1,863
4,010
8,173
10.6
21.4
30.4
66.8
151
335
735
1.1
1.9
2.4
5.1
10.8
23.1
105.9

FIGURE 3

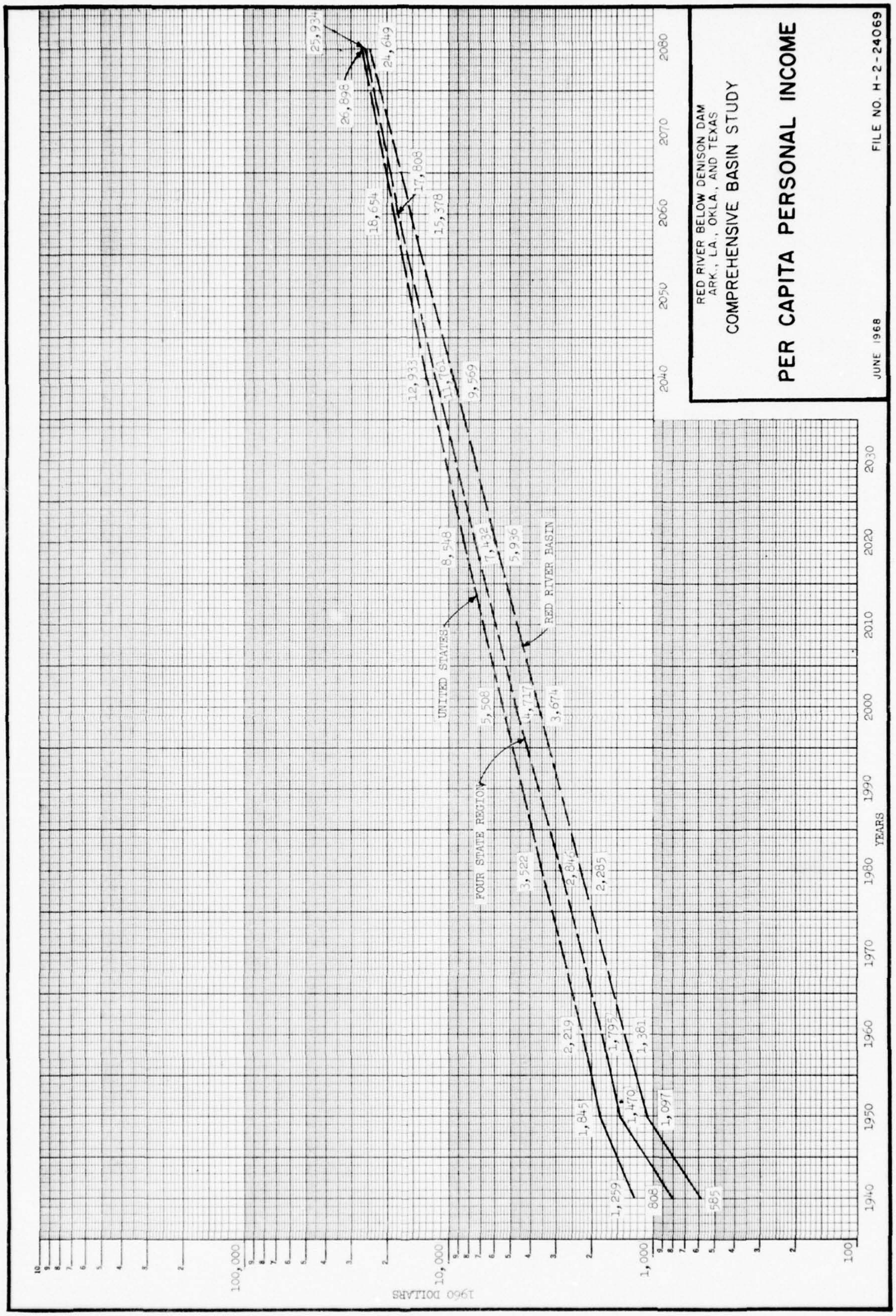

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
PER CAPITA PERSONAL INCOME
JUNE 1968
FILE NO. H-2-24069
FIGURE 4
1960 DOLLARS
YEARS
UNITED STATES
FOUR STATE REGION
RED RIVER BASIN
1,259
808
585
1,845
1,470
1,097
2,219
1,795
1,381
3,522
2,846
2,285
5,508
4,717
3,674
8,548
7,432
5,936
12,933
11,101
9,569
18,654
17,808
15,378
26,898
25,934
24,649

FIGURE 4

TABLE 9

VALUE ADDED BY MANUFACTURE[1]
(Millions of 1960 Dollars)

Year	United States	Average annual % change	Four-State Region	Average annual % change	Red River Basin	Average annual % change
1929	60,128.6		1,862.0		168.3	
		-0.75		-0.28		-2.70
1939	55,754.8		1,810.2		128.6	
		7.60		10.70		9.10
1947	100,079.9		4,075.3		257.2	
		3.90		6.75		6.30
1954	131,050.5		6,413.7		394.0	
		2.25		5.45		2.86
1958	143,238.7		7,931.7		441.0	
		6.00		6.70		6.90
1963	191,537.4		10,961.0		615.7	
1929-1963		3.45		5.36		3.90

(1)U. S. Department of Commerce, Bureau of the Census, <u>Census of Manufactures</u>

d. Projected value added by manufacture. Projected value added by manufacture for the United States to the year 2020 was furnished by the Southwestern Division of the Corps of Engineers. The figures from 2020 to 2080 were obtained by extending the 1960 to 2020 data by a slightly lower average annual percent increase. Value added by manufacture for the four-state region and the Red River Basin was projected at rates derived by simple regression analysis relating the figures of the two areas to those of the United States. All projections are based on a logical future expansion in existing industries coupled with an expanding national and regional industrial base. Table 10 and figure 5 show projected value added by manufacture to the year 2080 for the United States, the four-state region, and the Red River Basin.

22. VALUE OF FARM PRODUCTS SOLD

a. Historical value of farm products sold. Data on the value of farm products sold for the United States, the four-state region, and the Red River Basin during the period 1940-1959 are presented in table 11. The value of farm products sold in the basin area decreased from 1.2 percent of the United States total value in 1940 to 0.9 percent in 1959. The year 1954 was a drought year in most of the basin area and reflects the decreased output of that area. The basin area has produced about 8 percent of the total value of farm products sold in the four-state region for the period reported.

Table 12 presents additional data on the value of farm products sold and the average annual compound rates of increase or decrease for various periods. The long-term growth rate trend for the basin area has been 1.7 percent compared to 3.2 percent for the four-state region and 3.2 percent for the United States for the period 1940-1959. The basin area growth rate of 8.5 percent for the period 1954-1959 exceeded both the four-state region and the Nation increases of 5.6 percent and 4.5 percent, respectively.

b. Projected value of farm products sold. Population, per capita consumption of farm products, and net exports will largely determine the future production of agricultural products. Presently the basin area has a great capacity to produce, but surplus production in some cases has weakened the price structure. Over the long term, as population in the United States and in the world increases, surplus commodities will no longer exist and production volumes when combined with better distribution will come to a closer balance with needs. This is not to say that all problems of surplus and under supply will be solved, but, in general, a more even balance will exist between supply and demand. Projected value of farm products sold is assumed to be ample to support export requirements and at the same time meet growing demands from population increases.

TABLE 10

PROJECTED VALUE ADDED BY MANUFACTURE(1)
(Billions of Constant 1960 Dollars)

Year	United States	Four-State Region	Red River Basin
1939	55.75	1.81	0.13
1958	143.24	7.91	0.44
1963	191.54	10.96	0.62
1980	425.12	25.12	1.40
2000	1,005.84	63.00	3.46
2020	2,379.83	154.39	8.26
2040	5,471.00	355.00	19.08
2060	12,577.36	820.00	43.96
2080	28,914.21	1,890.00	101.14
	AVERAGE ANNUAL GROWTH RATE		
1963-1980	4.80	5.00	4.90
1963-2020	4.55	4.75	4.65
1963-2080	4.40	4.50	4.45

(1)Department of the Army, SWD Corps of Engineers and NOD Corps of Engineers.

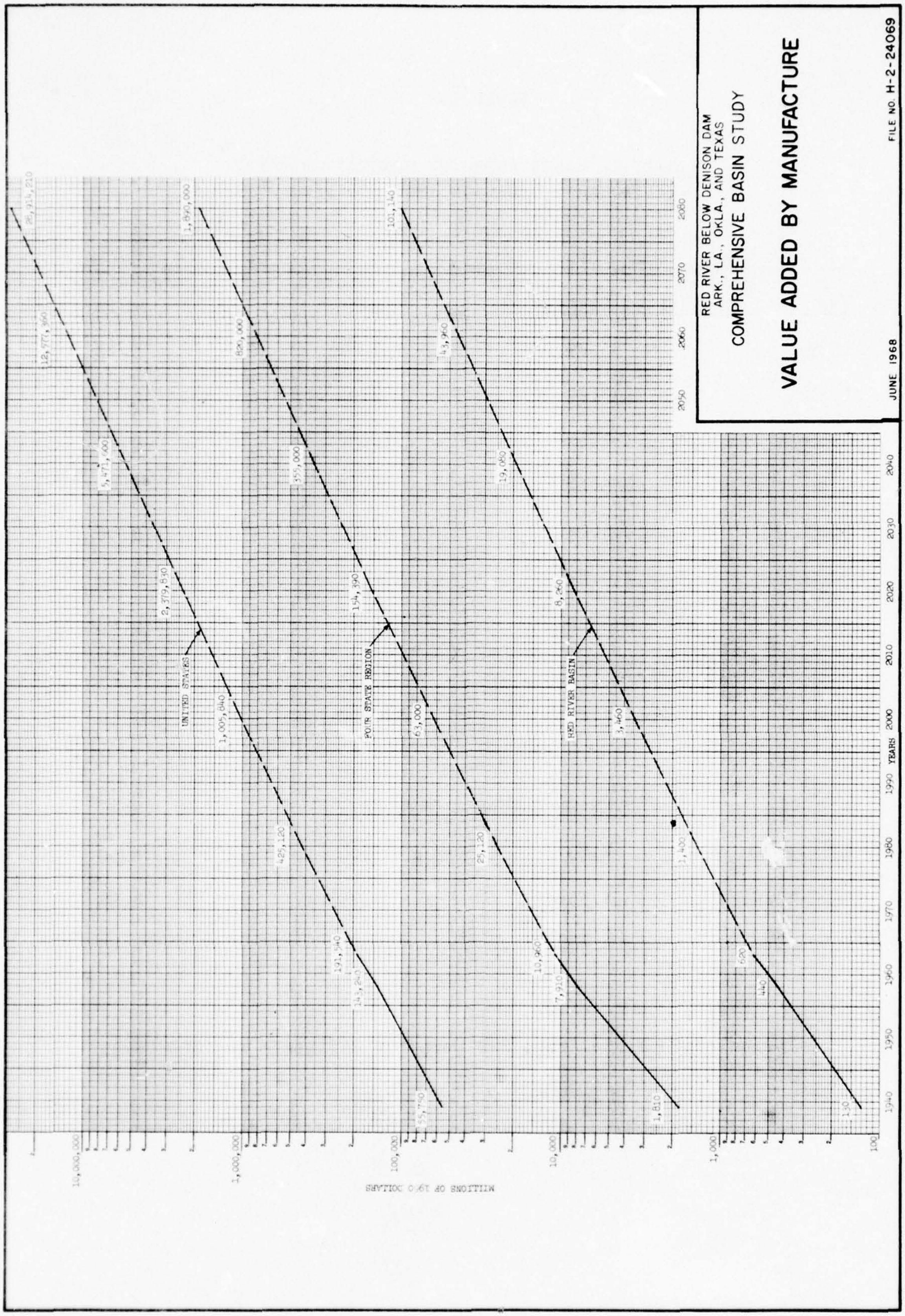

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
VALUE ADDED BY MANUFACTURE
JUNE 1968
FILE NO. H-2-24069
FIGURE 5
UNITED STATES
FOUR STATE REGION
RED RIVER BASIN
MILLIONS OF 1970 DOLLARS
YEARS
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
10,000,000
1,000,000
100,000
10,000
1,000
100
55,750
143,240
191,540
425,120
1,005,840
2,379,830
12,977,360
1,810
7,910
10,960
25,120
63,000
154,390
355,000
820,000
1,890,000
130
440
620
1,400
3,460
8,260
19,080
43,960
101,140

FIGURE 5

TABLE 11

VALUE OF FARM PRODUCTS SOLD[1]
(Millions of 1960 Dollars)

Year	U. S. Total	Four-State Region	Red River Basin	Basin % of Four-State Region	Basin % of U. S.
1940	16,704.0	1,987.4	199.9	10.1	1.2
1945	19,555.0	2,087.1	184.2	8.8	0.9
1949	21,000.9	2,725.2	204.8	7.5	1.0
1954	23,926.9	2,760.3	183.9	6.7	0.8
1959	30,402.1	3,633.3	276.0	7.6	0.9

(1) U. S. Department of Commerce, Bureau of the Census, Census of Agriculture, 1959, 1954, 1949, and 1945.

TABLE 12

VALUE OF FARM PRODUCTS SOLD[1], PERCENT CHANGE
(Millions of 1960 Dollars)

	United States	Four-State Region	Red River Basin
1940	16,704.0	1,987.4	199.9
Percent Change	2.7%	0.8%	-1.65%
1945	19,555.0	2,087.1	184.2
Percent Change	1.8%	6.9%	2.69%
1949	21,000.9	2,725.2	204.8
Percent Change	2.6%	0.3%	-2.19%
1954	23,926.9	2,760.3	183.9
Percent Change	4.5%	5.6%	8.5%
1959	30,402.1	3,633.3	276.0
1940	16,704.0	1,987.4	199.9
Percent Change	3.2%	3.2%	1.7%
1959	30,402.1	3,633.3	276.0

(1) U. S. Department of Commerce, Bureau of the Census, Census of Agriculture, 1959, 1954, 1949, and 1945.

Projected value of farm products sold for the United States to the year 2020 was furnished by the Southwestern Division, Corps of Engineers. The figures from 2020 to 2080 were obtained by extending the 1960 to 2020 data by a similar average annual percent increase. Projected values of farm products sold for the four-state region and the Red River Basin were derived by taking their proportional share (historically) of the projected United States figures. Table 13 and figure 6 present projected value of farm products sold to the year 2080 for the United States, the four-state region, and the Red River Basin.

TABLE 13

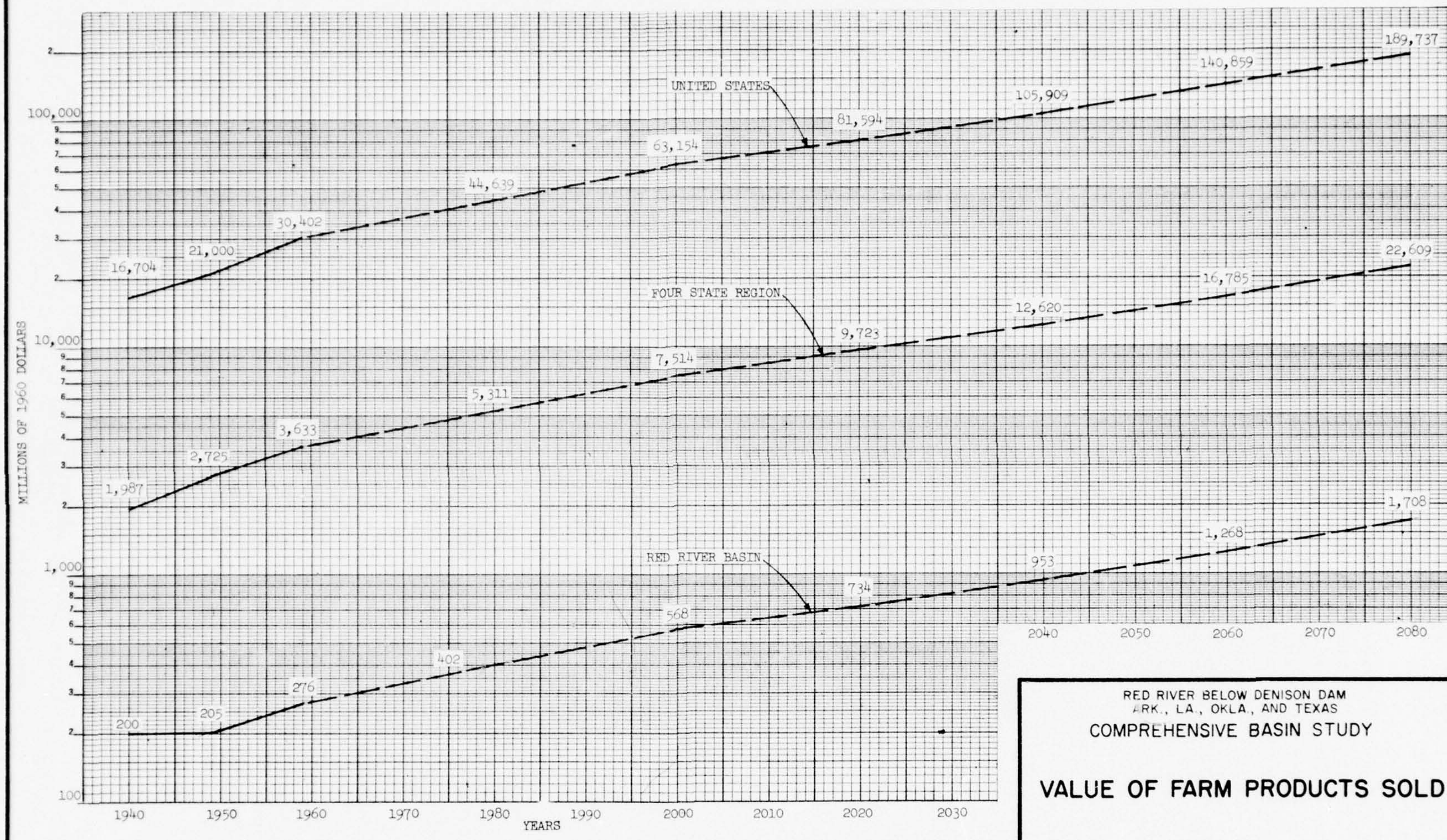
PROJECTED VALUE OF FARM PRODUCTS SOLD[1]
(Millions of 1960 Dollars)

Year	United States	Four-State Region	Red River Basin
1959	30,402	3,633	276
1980	44,639	5,311	402
2000	63,154	7,514	568
2020	81,594	9,723	734
2040	105,909	12,620	953
2060	140,859	16,785	1,268
2080	189,737	22,609	1,708

(1)Department of Army, SWD Corps of Engineers and NOD Corps of Engineers.

23. SUMMARY

A summary of historical and projected growth rates for the economic indicators presented in this study is shown in table 14. Although the basin area is expected to show an improvement in growth of population and employed labor force, it is not expected to reach the national average during the next hundred years. However, the other indicators (personal income, per capita income, value added by manufacture, and value of farm products sold) are expected to equal or exceed the national rates.



RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

VALUE OF FARM PRODUCTS SOLD

JUNE 1968 FILE NO. H-2-24069

FIGURE 6

FIGURE 6

TABLE 14

SUMMARY OF GROWTH RATES
AVERAGE ANNUAL PERCENT CHANGE

Economic Indicator	United States Historical	United States Projected		Four-State Region Historical	Four-State Region Projected		Red River Basin Historical	Red River Basin Projected	
Population									
Period	1930-1960	1960-2020	1960-2080	1930-1960	1960-2020	1960-2080	1930-1960	1960-2020	1960-2080
Percent	1.3	1.6	1.6	1.1	1.6	1.6	-	1.4	1.4
Employed Labor Force									
Period	1940-1960	1960-2020	1960-2080	1940-1960	1960-2020	1960-2080	1950-1960	1960-2020	1960-2080
Percent	1.8	1.7	1.7	2.0	1.7	1.7	-0.3	1.5	1.5
Personal Income									
Period	1930-1964	1964-2020	1964-2080	1930-1964	1964-2020	1964-2080	1930-1964	1964-2020	1964-2080
Percent	3.7	3.9	3.8	4.6	4.0	3.9	3.5	3.9	3.9
Per Capita Income									
Period	1930-1960	1960-2020	1960-2080	1930-1960	1960-2020	1960-2080	1930-1960	1960-2020	1960-2080
Percent	2.3	2.3	2.1	3.4	2.4	2.3	3.5	2.4	2.4
Value Added By Manufacture									
Period	1929-1963	1963-2020	1963-2080	1929-1963	1963-2020	1963-2080	1929-1963	1963-2020	1963-2080
Percent	3.5	4.6	4.4	5.4	4.8	4.5	3.9	4.7	4.5
Value of Farm Products Sold									
Period	1940-1959	1959-2020	1959-2080	1940-1959	1959-2020	1959-2080	1940-1959	1959-2020	1959-2080
Percent	3.2	1.6	1.5	3.2	1.6	1.5	1.7	1.6	1.5

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RED RIVER BELOW DENISON DAM
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS
COMPREHENSIVE BASIN STUDY

APPENDIX II

CLIMATE AND METEOROLOGY

Prepared by
U. S. Department of Commerce
Environmental Science Services Administration
Weather Bureau

June 1968

APPENDIX II

CLIMATE AND METEOROLOGY

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APPENDIX II

CLIMATE AND METEOROLOGY

SUMMARY

The Environmental Data Service, Department of Commerce, ESSA, publishes Climatological Data and Hourly Precipitation Data monthly and annually for Arkansas, Louisiana, Oklahoma and Texas. Local climatological summaries are occasionally prepared for specific communities and areas.

The Weather Bureau, also under ESSA, provides meteorological and hydrologic forecast services for the basin. These are available through first order Weather Bureau stations within and adjacent to the basin, and at Southern Region Headquarters at Fort Worth, Texas.

The climate of the Red River Basin below Denison Dam is revealed by studies of the records collected at Texarkana, Arkansas, Shreveport, Louisiana, 17 climatological stations in Arkansas, 37 in Louisiana, 27 in Oklahoma, and 31 in Texas. Climatological summaries have been prepared for Texarkana and Shreveport and are included in this appendix.

CHAPTER I - CLIMATOLOGICAL DATA

1. PURPOSE

The purpose of this appendix is to briefly describe the climate and meteorology of the basin and to present examples and sources of climatological and meteorological data published by the Environmental Science Services Administration. Appended is a description of the River and Flood Forecast Services provided for the basin by ESSA through the Weather Bureau.

2. GENERAL DESCRIPTION

The factor that determines the climate of the basin is its variable exposure to air masses of rather different properties. In summer, under the prevailing influence of maritime tropical air bringing moisture inland from the Gulf of Mexico, a regime favorable for convective thundershowers is established. Occasional westerly and northerly winds accompanying incursions of continental tropical and maritime polar air masses bring hotter and drier weather. During winter, portions of the basin are subjected alternately to tropical and polar air mass influence. Although modified by its southerly journey, the colder air occasionally brings large and rather sudden drops in temperature. The lower half of the basin is beyond the usual limit of winter polar outbreaks, but occasionally one does move this far south.

The climate varies in classification from moist sub-humid to humid; i.e., the precipitation generally equals or exceeds potential evapotranspiration. Despite this usually abundant rainfall, short periods of dry weather are frequent over small areas. Occasionally, droughts of longer duration involving large areas occur.

3. TEMPERATURE

The annual mean temperature is 65°F. The maximum recorded temperature was 118°F at Hugo, Oklahoma and Mount Pleasant, Texas on August 10, 1936. Smithville, Oklahoma recorded the minimum of -22°F on February 2, 1951.

The growing season has a length of about eight months, with the first killing frost usually occurring about the middle of November, and the last killing frost occurring in March. Monthly normal temperature based on records of the stations in those portions of the four states within the basin are presented in Table 1.

Table 1
Monthly Normal Temperature by Climatological Division
(Degrees F)

	Southeast Oklahoma	Northeast Texas	Southwest Arkansas	Northwest Louisiana
January	42.4	44.8	45.7	49.0
February	46.2	48.0	48.8	51.8
March	53.5	54.6	55.2	57.7
April	63.0	63.8	64.1	65.9
May	70.1	71.8	71.6	73.0
June	79.1	79.9	79.4	80.3
July	83.2	83.2	82.5	82.8
August	83.4	83.4	82.5	82.7
September	75.8	76.9	76.5	77.1
October	65.8	66.8	66.2	67.4
November	52.1	53.7	53.7	55.9
December	44.3	46.8	47.2	50.4

4. PRECIPITATION

Precipitation is predominantly of the rain shower type, except for occasional periods of continuous general rains during the late fall, winter, and early spring. The average number of days with measurable precipitation is about 60 per year. The greatest precipitation depth recorded in a single month was 25.45 inches at Shreveport, Louisiana in July 1933. The smallest recorded is zero, and has occurred at many stations in one or more calendar months. Average annual precipitation varies from less than 37 inches to over 59 inches. Average monthly precipitation is distributed as shown in Table 2.

Table 2
Average Precipitation by Climatological Division
(Inches)

	Southeast Oklahoma	Northeast Texas	Southwest Arkansas	Northwest Louisiana
January	3.05	3.83	4.78	5.43
February	3.35	3.68	4.28	4.72
March	3.51	3.93	4.65	4.87
April	4.72	4.95	5.41	5.22
May	5.91	5.33	5.01	5.57
June	4.00	3.77	3.54	3.70
July	3.36	3.41	3.99	4.41
August	2.89	2.69	2.94	3.25
September	3.46	2.97	2.80	2.92
October	3.30	3.13	3.00	2.94
November	3.15	3.95	4.51	4.59
December	3.02	4.01	4.71	5.43

The annual precipitation maximum was 109.38 inches recorded at Clarksville, Texas in 1873, and the minimum was 12.72 inches at Bonham, Texas in 1910.

Showfall is a minor part of the basin inflow, occurring about once every 2 to 3 years. Average snowfall varies from a maximum of 4 inches in Southern Oklahoma to 3.1 inches in Southwest Arkansas, 2.4 inches in Northwest Texas, and 1.7 inches in Northwest Louisiana.

5. WIND

The prevailing wind in the upper half of the basin, above Fultin, Arkansas is south at 11 miles per hour. Below Fulton, the prevailing wind is woutheast at 8 miles per hour.

6. EVAPORATION

Average evaporation is computed for two stations as indicated in Table 3.

Table 3
Average Pan Evaporation
(Inches)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
Denison Dam Tex.	2.4	3.3	5.7	7.2	8.2	9.9	10.9	10.6	7.6	5.3	3.8	2.5
Hope, Arkansas	2.2	2.6	4.2	5.3	6.3	6.8	7.7	7.4	5.7	4.5	2.6	1.9

7. GENERAL

River and Flood forecast service is provided by the River District Office at the ESSA Weather Bureau Airport Station at Shreveport, Louisiana. Data to formulate forecasts are collected by the River District Office from cooperative rainfall and river observers within and adjacent to the basin, from cooperating Federal, state, and local water resources agencies, and from official first-order ESSA Weather Bureau stations via telephone and teletypewriter. Weather search radars operated by Weather Bureau stations at Shreveport, Louisiana and Fort Smith, Arkansas (WSR3), and at Oklahoma City, Oklahoma, Fort Worth, Texas, and Little Rock, Arkansas (WSR57), provide information on areal coverage, duration, and intensity of precipitation.

Daily stage forecasts are prepared for several Red River main stem stations, and crest forecasts for a greater number of main stem and tributary stations where need exist and data are available. When excessive rains are reported or radar-detected, flash,flood warnings are issued to vulnerable areas.

Key stations stage forecasts are provided to the Shreveport River District Office by the River Forecast Center at Tulsa, Oklahoma. At present, this service is provided only for the main stem and tricutary area from Denison Dam to Fulton, Arkansas. In this area the River District Office adapts key point forecasts to provide general service. In the basin below Fulton, the River District Office originates all forecasts.

Forecast dissemination is largely provided by news media through the use of the ESSA Weather Wire Service, a teletypewriter network available to all bona fide mass news disseminators. The Shreveport office places all forecasts on the circuit for Louisiana dissemination. Forecasts for those portions of the basin in adjacent states are automatically transmitted to the proper state Weather Wire circuits.

Scheduled improvement and expansion is indefinite for this form of flood-loss abatement. It is planned, however, eventually to provide River Forecast Center service to the entire Red River Basin below Denison Dam. Also included is an expanded network of modern WSR57 radars, which will eventually provide overall full-time precipitation surveillance. The use of modern digital computers is also envisioned to accelerate and expand river and flood forecast formulation.

Table 4
Normal Precipitation for Selected Stations
(Inches)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Plain Dealing, La.	4.68	4.30	4.51	5.59	4.91	3.06	3.93	3.02	2.50	2.69	4.53	5.10	46.65
Hope, Ark.	5.21	4.46	5.01	5.60	5.14	3.76	4.09	3.26	2.93	3.17	4.57	4.46	47.68
Mount Ida, Ark.	4.67	4.33	5.18	5.44	6.13	3.75	4.44	3.46	3.82	3.62	4.45	4.61	53.90
Okay, Ark.	4.55	4.03	4.70	5.02	5.27	3.68	3.94	2.94	3.41	3.39	4.35	4.28	49.58
Hugo, Okla.	3.54	3.31	3.83	5.25	5.94	4.34	3.65	3.54	3.59	3.44	3.50	3.25	47.08
Poteau, Okla.	3.04	3.53	3.84	4.46	6.00	3.88	3.42	3.40	3.53	3.22	3.47	3.80	44.59

Table 5
Normal Temperature for Selected Stations
(Degrees F.)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Hope, Ark.	43.7	46.6	53.2	62.8	70.6	78.8	82.0	82.0	75.6	64.9	52.0	45.2	63.1
Mount Ida, Ark.	41.4	44.1	50.5	60.4	68.0	73.6	80.2	79.7	72.7	62.0	49.5	41.7	60.6
Okay, Ark.	46.0	49.1	55.6	64.5	71.6	79.3	82.6	82.2	76.2	66.0	53.7	47.2	65.5
Plain Dealing, La.	46.4	49.5	55.8	64.6	72.1	79.9	82.9	83.0	77.4	67.1	53.5	48.2	65.1
Hugo, Okla.	43.4	47.1	54.2	63.6	72.0	79.3	83.1	82.0	76.3	65.9	52.9	45.8	63.8
Poteau, Okla.	42.6	46.1	53.0	59.8	70.3	79.0	83.5	83.2	76.1	65.1	52.0	44.7	63.2

Table 6
Index of Published Temperature and Precipitation Data Stations

ARKANSAS

Station	Index	Divn.	County	Lat.	Long.	Elev.	Yrs. of Record Temp.	Yrs. of Record Precip.
Athens	0300	7	Howard	34°19'	93°58'	960		19
Cove	1666	4	Polk	34°26'	94°25'	1050		18
DeQueen	1948	7	Howard	34°02'	94°21'	420	33	33
Dierks	2015	7	Sevier	34°07'	94°02'	420	8	8
Foreman	2544	7	Little River	33°43'	94°24'	400		27
Fulton	2670	7	Hempstead	33°37'	93°48'	260		81
Hope 3NE	3428	7	Hempstead	33°43'	93°33'	375	96	96
Horatio	3442	7	Sevier	33°56'	94°22'	340		21
Index	3584	7	Little River	33°35'	94°03'	300		42
Magnolia 3N	4548	8	Columbia	33°19'	93°14'	320	50	50
Magnolia #2	4550	8	Columbia	33°16'	93°14'	290		17
Millwood Dam	4839	7	Little River	33°41'	93°58'	320		4
Mount Ida	4988	7	Montgomery	34°33'	93°83'	663	67	67
Nashville Peach Sta.	5112	7	Howard	34°00'	93°56'	550	28	28
Okay	5376	7	Howard	33°46'	93°55'	300	38	38
Ravana	6016	7	Miller	33°04'	94°02'	250		26
Stamps	6804	7	Lafayette	33°22'	93°29'	270	5	19
Taylor	7038	8	Columbia	33°06'	93°27'	250		24
Texarkana WB AP	7048	7	Miller	33°27'	94°00'	360	82	82

LOUISIANA

Station	Index	Divn.	County	Lat.	Long.	Elev.	Yrs. of Record Temp.	Yrs. of Record Precip.
Alexandria	0098	5	Rapides	31°19'	92°28'	90	72	79
Alexandria Pineville Bridge	0101	5	Rapides	31°19'	92°27'			19
Arcadia	0277	2	Bienville	32°33'	92°55'	400	36	36
Ashland 2S	0349	4	Natchitoches	32°07'	93°06'	230	13	23
Belah Fire Tower	0639	5	LaSalle	31°38'	92°11'	200	15	15

Table 6 (Cont'd)

LOUISIANA

Station	Index	Divn.	County	Lat.	Long.	Elev.	Yrs. of Record Temp.	Yrs. of Record Precip.
Bethany	0736	1	Caddo	32°23'	94°03'	320		5
Bodcau Fire Tower	0920	1	Bossier	32°42'	93°31'			15
Book	1152	5	Catahoula	31°20'	91°52'	50	8	16
Chatham	1703	2	Jackson	32°19'	92°27'	180	20	24
Colfax	1941	5	Grant	31°31'	92°43'	90	20	30
Cotton Valley	2121	1	Webster	32°49'	93°25'	230	19	23
Coushatta #2	2143	N	Red River	32°01'	93°21'	140		12
Curtis 1SSE	2235	1	Bossier	32°25'	93°38'	160		2
Gloster 1W	3657	1	DeSoto	32°12'	93°50'	260		21
Gorum Fire Tower	3741	4	Natchitoches	31°25'	92°54'	360	13	14
Grand Ecore	3804	4	Natchitoches	31°48'	93°06'	150		19
Homer Exp. Sta.	4355	2	Claiborne	32°45'	93°04'	370	17	17
Hosston	4398	1	Caddo	32°53'	93°53'	200		27
Keithville	4816	1	Caddo	32°21'	93°50'	200		24
Koran	4931	1	Bossier	32°25'	93°28'	180		20
Lake End	5081	1	Red River	31°55'	93°18'	130		25
Martin Fire Tower	5935	1	Red River	32°06'	93°14'	270		2
Minden	6244	1	Webster	32°36'	93°18'	250	79	80
Montgomery	6324	5	Grant	31°40'	92°54'	170		27
Natchitoches	6582	4	Natchitoches	31°46'	93°05'	120	47	47
Olla 1S	6978	5	LaSalle	31°54'	92°14'	160		16
Plain Dealing	7344	1	Bossier	32°54'	93°41'	290	75	75
Pollock 6NNW	7424	5	Grant	31°36'	92°26'	200		11
Rodessa	7950	1	Caddo	32°58'	94°00'	200		27
Sailes Fire Tower	8094	2	Bienville	32°22'	93°08'	360		15
Shreveport WB AP	8440	1	Caddo	32°28'	93°49'	110	95	95
Sikes 2E	8489	2	Winn	32°05'	92°28'	180		14
Springhill	8683	1	Webster	33°00'	93°27'	240		20
Urania	9235	5	LaSalle	31°52'	92°18'	100	38	38
Westdale 3SW	9610	1	Red River	32°08'	93°30'	140	14	14
Winnfield 2W	9803	2	Winn	31°56'	92°41'	160	28	28
Winona Fire Tower	9809	2	Winn	32°02'	92°39'	220		15

Table 6 (Cont'd)

OKLAHOMA

Station	Index	Divn.	County	Lat.	Long.	Elev.	Yrs. of Record Temp.	Yrs. of Record Precip.
Antlers 2ENE	0256	9	Pushmataha	34°15'	95°36'	470	49	49
Atoka 3SW	0391	8	Atoka	34°20'	96°09'	670	39	39
Atoka Dam	0394	8	Atoka	34°26'	96°05'	630	5	5
Bear Mtn. Tower	0584	9	McCurtain	34°08'	94°57'	800	8	27
Boswell 5NNW	0980	9	Choctaw	34°05'	95°54'	530	8	23
Broken Bow 1N	1162	9	McCurtain	34°03'	94°44'	480		26
Broken Bow Dam	1168	9	McCurtain	34°09'	94°41'	660	4	4
Caney 1SE	1436	8	Atoka	34°14'	96°12'	540		23
Carnasaw Tower	1499	9	McCurtain	34°09'	94°38'	1000		27
Carter Tower	1544	9	McCurtain	34°15'	94°47'	1300		27
Clayton	1855	9	Pushmataha	34°35'	95°21'	600	20	20
Cloudy Tower	1936	9	Pushmataha	34°23'	95°15'	1200		27
Daisy 2ENE	2354	8	Atoka	34°33'	95°42'	730		23
Durant SE St. College	2678	8	Bryan	34°01'	96°23'	690	65	65
Farris 3WNW	3083	8	Atoka	34°17'	95°55'	570		19
Flashman Tower	3182	9	McCurtain	34°29'	95°00'	1750	8	27
Hee Mtn. Tower	4017	9	McCurtain	34°20'	94°39'	1500		19
Hugo	4384	9	Choctaw	34°01'	95°31'	540		19
Idabel	4451	9	McCurtain	34°53'	94°49'	460	50	50
Kiamichi Tower	4820	9	LeFlore	34°38'	94°49'	2600	8	27
Pine Creek Dam	7080	9	McCurtain	34°14'	95°05'	490		3
Poteau	7246	9	LeFlore	35°04'	94°38'	572	53	53
Signal Mtn. Tower	8197	9	Pushmataha	34°19'	95°03'	1350		19
Smithville 3NNW	8285	9	McCurtain	34°30'	94°39'	960	5	45
Sobol Tower	8305	9	Choctaw	34°08'	95°14'	750		15
Tuskahoma	9023	9	Pushmataha	34°37'	95°17'	600		24
Valliant 1E	9118	9	McCurtain	34°00'	95°05'	520		25
Yuba 2W	9841	8	Bryan	33°49'	96°14'	610		16

Table 6 (Cont'd)

TEXAS

Station	Index	Divn.	County	Lat.	Long.	Elev.	Yrs. of Record Temp.	Yrs. of Record Precip.
Arthur City	0367	3	Lamar	33°53'	95°30'	410		76
Atlanta	0408	4	Cass	33°07'	94°11'	250		27
Bonham	0923	3	Fannin	33°36'	96°11'	570	63	63
Boxelder	0991	4	Red River	33°29'	94°29'	350		19
Clarksville 2E	1772	4	Red River	33°37'	95°01'	420	64	73
Clarksville 1W	1773	4	Red River	33°37'	95°04'	470		25
Commerce	1921	3	Hunt	33°15'	95°53'	550		20
Cooper	1970	3	Delta	33°23'	95°42'	500		23
Daingerfield 9S	2225	4	Morris	32°55'	94°43'	300	8	23
DeKalb 2N	2352	4	Bowie	33°32'	94°37'	370		20
Deport	2415	3	Lamar	33°31'	95°19'	420		23
Gilmer 2W	3546	4	Upshur	32°44'	94°59'	390	51	51
Hagansport	3846	4	Red River	33°23'	95°14'	320		24
Harleton	3941	4	Harrison	32°41'	94°35'	290		18
Honey Grove	4257	3	Fannin	33°35'	95°54'	670		51
Jefferson	4577	4	Marion	32°46'	94°21'	210		57
Karnack	4693	4	Harrison	32°41'	94°09'	230	25	25
Linden	5229	4	Cass	33°01'	94°22'	390		27
Maud	5667	4	Bowie	33°20'	94°21'	310		27
Mt. Pleasant	6108	4	Titus	33°10'	95°00'	420	51	51
Mt. Vernon	6119	4	Franklin	33°11'	95°14'	480	2	2
Naples 1SW	6190	4	Bowie	33°11'	94°41'	360		57
Negley 4SSW	6247	4	Red River	33°42'	95°04'	400		21
Paris	6794	3	Lamar	33°40'	95°34'	540	79	84
Pittsburg 5S	7066	4	Camp	32°56'	94°58'	350		18
Simms 2NW	8335	4	Bowie	33°22'	94°30'	360	5	5
Sulphur Springs	8743	4	Hopkins	33°08'	95°36'	500	39	63
Telephone	8898	3	Fannin	33°47'	96°02'	520		7
Texarkana Dam	8944	4	Cass	33°18'	94°10'	280	12	20
Winnsboro 6SW	9836	4	Wood	32°53'	95°20'	430		23
Wolfe City	9859	3	Hunt	33°22'	96°04'	670		23

LOCAL CLIMATOLOGICAL DATA
ANNUAL SUMMARY WITH COMPARATIVE DATA, 1966

SHREVEPORT, LOUISIANA

NARRATIVE CLIMATOLOGICAL SUMMARY

Shreveport is located along the west bank of the Red River in the northwest corner of the state some 30 miles south of the Arkansas line and 13 miles east of the Texas line. About half of the City is located in the river bottom and the rest of the City is in the gentle rolling hills that begin about a mile west of the river. The airport is located in the hills some 7 miles southwest of the downtown section.

Summer months of June, July, and August are warm and rather humid with widely scattered afternoon showers and thundershowers in the area about half of the time. Showers fall at any one place in the area on about 8 days during each of these months. Humidity during these months range from an average of about 90 percent during the early mornings to a little over 50 percent in the mid-afternoons.

Winter months are normally mild with cold spells of short duration, turning cold one day, reaching the lowest temperature on the second day, and warming beginning on the third day. Snowfall since 1877 has averaged a little over an inch and a half per year, although measurable snow is recorded only about every other year. The greatest single snow was in December 1929, when 11 inches was recorded. This snow fell on the 21st and 22d and about 1/2 inch was still on the ground on December 25, making the only Christmas Day of record with measurable snow on the ground. More troublesome than snowfall are the occasional ice and sleet storms which do considerable damage to trees, power and telephone lines, as well as making travel very difficult.

Freezing temperatures are recorded on an average of 32 days during the year. Since 1874 the average date of earliest freeze in the fall is November 13, and the average date of the latest freeze in the spring is March 5. Freezing temperatures have been recorded as early as October 20 and as late as April 13. Temperatures recorded here at the airport on clear calm nights are normally 2° - 5° warmer than the low-lying river bottomland in the vicnity.

By March, trees and grass are becoming green and early spring planting is generally well under way before the end of the month. Subtropical vegetation and flowers such as Magnolia, Camellia, and Gardenia need only occasional protection to survive. Roses often bloom into December and begin blooming again by late March.

U.S. DEPARTMENT OF COMMERCE
JOHN T. CONNOR, Secretary
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
ROBERT M. WHITE, Administrator
ENVIRONMENTAL DATA SERVICE

LATITUDE 32° 28' N
LONGITUDE 93° 49' W
ELEVATION (ground) 254 Feet

METEOROLOGICAL DATA FOR THE CURRENT YEAR

SHREVEPORT, LOUISIANA
MUNICIPAL AIRPORT
1966

Month	Temperature: Averages: Daily maximum	Daily minimum	Monthly	Extremes: Highest	Date	Lowest	Date	Degree days	Precipitation: Total	Greatest in 24 hrs	Date	Snow, Sleet: Total	Greatest in 24 hrs	Date
JAN	49.8	34.7	42.3	71	1	13	30	703	4.22	1.22	28	0.2	0.2	21
FEB	57.3	37.7	47.5	75	7	24	3	485	3.45	2.30	9-10	1.3	1.3	23
MAR	69.9	46.3	58.1	89	31	28	7	238	0.56	0.36	12-13	0.0	0.0	
APR	76.7	55.7	66.2	87	28+	37	5	62	8.02	2.03	25-26	0.0	0.0	
MAY	81.8	63.5	72.7	91	17	52	10+	8	3.78	1.78	18	0.0	0.0	
JUN	89.5	68.4	79.0	95	29+	58	2+	0	2.05	1.97	13	0.0	0.0	
JUL	95.3	74.7	85.0	101	15	70	1	0	0.58	0.32	20-21	0.0	0.0	
AUG	90.6	71.4	81.0	97	8+	61	26	0	1.71	1.25	12	0.0	0.0	
SEP	84.4	66.2	75.3	93	6	56	22	0	3.27	1.70	10-11	0.0	0.0	
OCT	76.5	51.4	64.0	90	9+	38	20	99	1.62	0.76	17	0.0	0.0	
NOV	72.0	48.8	60.4	81	8	24	3	181	2.47	0.53	26	0.0	0.0	
DEC	55.7	38.1	46.9	81	7	20	25+	570	3.63	0.95	8	T	T	30+
YEAR	75.0	54.7	64.9	101	JUL. 15	13	JAN. 30	2346	33.86	2.30	FEB. 9-10	1.5	1.3	FEB. 23

Month	Relative humidity: Midnight CST	6:00 A.M. CST	Noon CST	6:00 P.M. CST	Wind[&]: Resultant: Direction	Speed	Average speed	Fastest mile: Speed	Direction	Date	Percent of possible sunshine	Average sky cover sunrise to sunset
JAN	78	84	66	72	36	3.7	11.4	32	17	31	40	7.2
FEB	75	82	62	64	05	0.8	11.5	35	33	9	51	6.1
MAR	66	74	49	45	21	2.6	11.4	37	33	23	67	5.6
APR	73	83	57	57	18	4.2	12.3	35	34	30	47	6.5
MAY	83	88	61	61	09	3.3	9.5	23	17	17+	51	6.6
JUN	76	87	51	50	14	3.3	8.9	23	13	29	67	4.6
JUL	78	91	58	55	17	4.0	8.1	30	8	20	71	5.3
AUG	82	93	56	62	14	2.2	8.3	25	4	18	55	6.5
SEP	87	92	65	66	35	1.2	8.0	23	21	30	60	5.7
OCT	81	87	52	64	09	1.7	9.1	35	31	14	72	3.5
NOV	75	88	57	59	17	2.4	9.7	26	1	1	63	4.9
DEC	85	92	76	77	15	0.8	8.1	24	29	23	43	7.5
YEAR	78	87	59	60	14	1.5	9.7	37	33	MAR. 23	58	5.8

Month	Number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Maximum: 90 and above	32 and below	Minimum: 32 and below	0 and below
JAN	7	5	19	16	0	2	0	0	[illegible]	14	0
FEB	9	6	13	7	1	3	2	0	[illegible]	11	0
MAR	12	7	12	6	0	0	4	0	0	2	0
APR	7	10	13	13	0	12	2	0	0	0	0
MAY	6	9	16	9	0	6	0	1	0	0	0
JUN	11	15	4	4	0	2	0	18	0	0	0
JUL	12	12	7	7	0	5	0	28	0	0	0
AUG	5	11	15	6	0	8	0	21	0	0	0
SEP	9	9	12	7	0	2	0	8	0	0	0
OCT	15	10	6	4	0	1	2	2	0	0	0
NOV	10	11	9	3	0	2	6	1	0	3	0
DEC	5	7	19	14	0	2	5	0	0	13	0
YEAR	108	112	145	96	1	45	25	78	1	43	0

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year
(a)	(b)	(b)	(b)	14		14		(b)	(b)	14		14		14	
J	56.7	38.3	47.5	81	1957+	3	1962	552	4.80	5.07	1957	1.17	1959	2.32	1953
F	59.7	40.9	50.3	83	1956+	18	1958+	426	4.09	6.51	1965	0.90	1954	3.53	1965
M	66.5	46.6	56.6	89	1966+	22	1965	304	4.15	6.55	1957	0.56	1966	2.77	1960
A	75.4	55.2	65.3	91	1955	36	1961	81	4.57	11.19	1957	1.16	1965	7.17	1953
M	83.1	63.1	73.1	95	1953	42	1960	0	4.79	9.64	1955	1.22	1962	4.66	1955
J	90.6	70.5	80.6	101	1953	55	1955	0	3.34	12.39	1961	1.30	1953	4.10	1961
J	94.2	73.2	83.7	106	1954	64	1961	0	3.75	6.17	1955	0.15	1964	3.54	1955
A	94.8	72.7	83.8	107	1962	58	1956	0	2.55	6.83	1955	0.92	1954	4.64	1955
S	90.5	67.0	78.8	103	1956+	49	1963	0	2.28	8.58	1958	0.17	1956	5.39	1961
O	81.2	55.3	68.3	97	1954	31	1957+	47	2.81	6.78	1957	0.00	1963	3.88	1957
N	66.8	44.5	55.7	88	1955	22	1959	297	4.21	9.49	1957	0.83	1955	4.01	1963
D	59.1	40.0	49.6	84	1955	9	1963	477	4.94	8.10	1960	0.68	1958	3.35	1965
YR	76.6	55.6	66.1	107	AUG. 1962	3	JAN. 1962	2184	46.28	12.39	JUN. 1961	0.00	OCT. 1963	7.17	APR. 1953

Month	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity: Midnight CST	6:00 A.M. CST	Noon CST	6:00 P.M. CST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset
(a)	14	14		14		14	14	14	14	14	11				14	14
J	0.5	3.5	1962	3.5	1962	76	83	63	64	10.8	S				52	6.4
F	0.5	2.0	1965+	2.0	1965+	75	82	60	59	11.2	S				54	6.2
M	0.3	4.0	1965	4.0	1965	73	82	57	55	11.5	S				59	6.2
A	0.0	0.0		0.0		77	86	57	57	11.4	S				57	6.4
M	0.0	0.0		0.0		81	89	58	59	9.6	S				65	6.2
J	0.0	0.0		0.0		82	90	57	58	8.5	S				72	5.0
J	0.0	0.0		0.0		81	90	55	56	8.3	S				76	5.0
A	0.0	0.0		0.0		80	90	54	56	8.1	S				73	4.8
S	0.0	0.0		0.0		79	90	55	59	8.2	ENE				72	4.5
O	0.0	0.0		0.0		76	87	51	59	8.5	SSE				76	4.2
N	T	T	1959+	T	1959+	78	85	56	63	9.8	S				62	5.3
D	0.2	3.2	1963	3.0	1963	77	84	62	66	10.2	S				55	6.1
YR	1.5	4.0	MAR. 1965	4.0	MAR. 1965	78	86	57	59	9.7	S				66	5.5

Month	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max: 90 and above	32 and below	Min: 32 and below	0 and below
(a)	14	14	14	14	14	14	14	14	14	14	14
J	9	5	17	9	*	2	3	0	1	11	0
F	8	6	14	8	*	3	3	0	0	7	0
M	9	7	15	9	*	6	2	0	0	3	0
A	8	7	15	9	0	7	1	*	0	0	0
M	7	11	13	8	0	6	1	6	0	0	0
J	10	13	7	8	0	8	*	18	0	0	0
J	12	11	8	7	0	7	1	27	0	0	0
A	12	11	8	7	0	7	*	25	0	0	0
S	14	7	9	7	0	4	1	15	0	0	0
O	15	8	8	5	0	2	2	3	0	*	0
N	12	6	12	8	0	3	3	0	0	3	0
D	9	7	15	9	*	2	4	0	*	9	0
YR	125	99	141	94	1	54	21	94	1	34	0

Means and extremes in the above table are from the existing location. Annual extremes have been exceeded at other locations as follows: Highest temperature 110 in August 1909; lowest temperature -5 in February 1899.

(a) Length of record, years.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months or years.
T Trace, an amount too small to measure.
Below-zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F., precipitation, including snowfall, in inches, wind movement in miles per hour, and relative humidity in percent. Degree day totals are the sums of the negative departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North, i.e., 09 East, 18 South, 27 West, 36 North, and 00 Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1 minute values.

SHREVEPORT, LOUISIANA
MUNICIPAL AIRPORT

AVERAGE TEMPERATURE

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1931	49.1	53.8	[illegible]	63.2	69.0	81.6	84.2	80.3	82.1	72.3	62.0	53.0	66.9
1932	52.7	59.4	56.0	67.7	73.4	82.8	86.1	84.8	77.8	65.9	52.6	45.6	66.9
1933	55.7	49.1	59.0	65.9	77.8	81.8	82.4	83.0	82.8	68.2	59.0	50.2	68.6
1934	50.7	49.2	56.8	68.0	73.6	84.2	86.0	86.6	77.0	73.4	60.1	50.0	68.0
1935	50.8	52.2	64.4	65.8	71.6	80.0	84.8	84.8	75.8	70.4	56.0	45.5	66.8
1936	46.6	44.6	63.7	64.8	74.4	83.8	83.4	86.6	82.2	65.5	54.3	52.0	66.7
1937	50.2	51.1	54.4	66.6	76.0	82.4	83.6	84.4	77.9	66.2	53.6	50.6	66.4
1938	50.2	57.9	66.3	65.5	74.8	80.6	83.6	85.0	79.4	72.0	55.8	50.2	68.5
1939	[illegible]	51.2	62.0	65.0	74.7	82.4	86.0	85.3	82.4	69.2	54.5	54.4	68.3
1940	35.8	49.2	59.0	64.8	71.9	78.4	81.8	79.8	74.7	70.1	55.4	52.8	64.5
1941	51.2	47.3	53.1	67.8	75.0	79.6	83.8	84.6	79.6	73.1	53.6	50.4	66.6
1942	44.9	47.4	57.2	67.2	72.6	81.3	83.9	82.6	74.8	66.8	60.6	48.4	65.6
1943	48.2	53.4	53.4	68.0	76.4	83.6	85.0	86.8	75.2	65.6	53.2	47.0	66.3
1944	46.2	54.6	58.0	65.3	72.6	83.0	85.2	83.9	77.5	67.2	57.6	44.8	66.3
1945	45.7	52.6	64.0	66.8	71.4	80.6	81.3	81.8	79.0	65.0	59.8	44.4	66.0
1946	46.4	53.0	61.7	69.5	71.5	78.5	84.8	81.4	75.4	67.4	58.6	54.1	66.7
1947	47.4	43.4	51.2	67.1	71.8	81.0	82.4	85.6	78.9	72.2	53.0	49.7	65.3
1948	39.1	48.4	57.2	70.4	73.8	82.6	85.3	84.6	76.9	65.7	55.7	52.2	66.0
1949	48.2	53.0	57.4	64.2	77.0	81.8	83.6	81.1	75.4	67.4	58.3	51.2	66.6
1950	56.2	55.0	55.9	62.9	75.7	79.9	81.4	81.0	74.6	69.8	54.2	45.9	66.0
1951	48.2	50.6	57.9	63.5	73.6	81.3	84.6	87.5	77.5	68.1	52.0	51.6	66.3
1952	55.6	54.1	55.5	62.0	72.7	83.6	83.8	84.1	76.8	60.6	54.6	48.1	66.0
1953	51.4	50.7	63.2	63.6	74.7	84.6	82.0	82.3	78.0	69.7	54.2	45.9	66.7
1954	49.3	56.7	56.7	70.2	68.8	81.7	87.0	86.9	80.7	69.3	55.3	50.8	67.8
1955	47.9	49.9	59.7	69.3	75.7	77.5	82.5	81.2	79.6	66.7	55.3	49.4	66.2
1956	46.6	54.5	57.3	63.5	76.2	79.3	84.8	84.1	78.3	69.6	54.1	54.6	66.9
1957	47.4	56.8	54.8	65.1	74.5	79.8	83.8	82.3	74.6	63.5	55.5	52.6	65.9
1958	44.9	44.6	52.2	63.8	73.4	80.8	82.9	82.1	77.3	65.2	57.0	44.7	64.1
1959	45.2	50.5	55.8	62.6	75.5	78.4	81.6	81.9	78.2	67.3	50.2	50.4	64.8
1960	45.9	44.0	48.5	67.3	71.3	80.0	82.9	82.1	77.5	68.4	57.1	44.6	64.2
1961	43.4	52.7	61.2	62.7	71.7	75.5	79.5	79.0	76.5	66.7	54.7	48.1	64.3
1962	42.4	57.2	53.3	64.0	75.4	78.6	84.0	84.8	77.5	70.7	55.2	48.5	66.0
1963	39.6	46.4	62.2	68.7	74.8	82.1	83.7	85.0	78.4	71.9	58.0	39.9	66.0
1964	46.5	45.6	56.8	68.7	75.1	81.0	84.2	84.0	78.5	64.2	59.3	50.1	66.2
1965	50.8	49.4	49.6	70.1	73.7	78.4	83.0	82.1	77.2	66.1	63.2	52.0	66.3
1966	42.3	47.5	58.1	66.2	72.7	79.0	[illegible]	[illegible]	[illegible]	[illegible]	60.4	46.9	64.9
RECORD MEAN	47.5	50.9	58.0	66.2	73.4	80.6	83.2	82.8	77.3	67.2	56.3	49.3	66.1
MAX	56.3	60.2	68.0	76.2	83.2	90.4	93.0	92.8	87.5	78.1	66.4	58.2	75.9
MIN	38.6	41.5	48.0	56.1	63.6	70.7	73.4	72.7	67.1	56.3	46.1	40.3	56.2

TOTAL DEGREE DAYS

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
1930-31	0	0	1	101	293	566	494	314	397	109	31	0	2306
1931-32	0	0	0	37	148	379	348	203	356	28	0	0	1541
1932-33	0	0	0	65	379	508	307	452	224	72	1	0	2093
1933-34	0	0	0	31	186	244	442	442	278	30	2	0	1655
1934-35	0	0	0	7	187	466	447	330	126	66	11	0	1640
1935-36	0	0	3	32	307	607	633	602	91	124	0	0	2399
1936-37	0	0	1	84	343	406	470	396	338	73	0	0	2111
1937-38	0	0	4	85	354	446	450	243	69	108	4	0	1763
1938-39	0	0	0	29	305	463	398	392	165	86	0	0	1838
1939-40	0	0	1	67	320	338	923	467	216	105	1	0	2438
1940-41	0	0	16	17	293	373	428	498	374	48	0	0	2047
1941-42	0	0	0	44	347	451	627	465	272	40	6	0	2279
1942-43	0	0	31	50	404	524	546	328	376	50	0	0	2105
1943-44	0	0	1	90	367	561	580	309	237	79	19	0	2243
1944-45	0	0	0	57	262	630	597	364	105	52	10	0	2096
1945-46	0	0	0	81	231	639	572	342	119	30	6	0	2040
1946-47	0	0	1	52	230	353	556	604	428	48	0	0	2272
1947-48	0	0	2	2	363	475	806	488	293	25	2	0	2456
1948-49	0	0	0	71	301	425	536	342	244	110	0	0	2029
1949-50	0	0	9	81	241	428	311	298	311	128	0	0	1807
1950-51	0	0	2	10	352	594	513	411	246	126	4	0	2258
1951-52	0	0	0	39	400	434	327	310	308	122	7	0	1945
1952-53	0	0	0	184	342	519	416	394	110	89	16	0	2070
1953-54	0	0	0	54	328	588	479	240	293	27	47	0	2056
1954-55	0	0	0	81	285	437	528	428	249	34	0	0	2042
1955-56	0	0	0	79	351	493	569	319	267	111	0	0	2189
1956-57	0	0	0	23	334	344	568	249	308	91	15	0	1912
1957-58	0	0	0	115	310	384	616	564	391	87	4	0	2471
1958-59	0	0	0	85	261	621	609	402	287	127	0	0	2392
1959-60	0	0	0	61	462	443	598	608	511	37	23	0	2743
1960-61	0	0	0	43	251	626	661	342	167	148	15	5	2258
1961-62	0	0	1	71	320	528	690	227	356	104	1	0	2288
1962-63	0	0	0	47	294	502	785	512	162	30	11	0	2343
1963-64	0	0	0	12	234	772	568	556	254	35	0	0	2431
1964-65	0	0	6	93	216	479	446	432	473	28	0	0	2173
1965-66	0	0	3	78	103	400	703	485	218	67	4	0	2080
1966-67	0	0	0	99	181	570							

TOTAL PRECIPITATION

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct	Nov.	Dec.	Annual
1931	3.58	3.32	3.34	5.26	1.17	1.28	1.66	3.96	0.74	4.66	5.01	10.43	[illegible]
1932	10.51	5.90	5.95	2.61	1.34	3.27	1.04	1.58	0.61	1.17	1.98	7.01	42.97
1933	2.85	6.72	6.25	5.19	3.86	0.15	25.45	2.19	1.07	4.55	0.79	4.64	63.71
1934	5.91	2.75	9.30	4.13	4.46	0.95	0.41	0.73	1.51	T	9.12	4.06	43.33
1935	5.50	3.33	2.99	5.16	10.47	2.95	1.02	2.70	1.88	3.88	6.07	3.39	49.34
1936	1.77	1.40	2.65	2.18	2.69	0.39	3.27	0.39	0.84	4.09	2.34	4.43	26.44
1937	8.39	2.28	5.26	2.43	0.98	3.47	1.42	3.02	3.34	4.96	7.41	7.63	50.59
1938	2.25	2.38	4.95	6.51	3.31	4.04	4.00	2.05	1.33	0.37	5.82	3.15	40.16
1939	6.79	8.96	0.85	1.11	3.06	2.58	1.82	2.66	0.69	0.70	6.10	4.91	40.23
1940	2.24	4.77	2.22	8.58	4.46	5.53	5.06	8.61	0.36	2.33	10.09	7.91	62.16
1941	3.57	3.84	3.69	2.49	8.52	4.26	4.00	1.90	2.77	8.83	4.10	3.37	51.34
1942	1.12	1.34	3.02	10.34	8.00	6.04	0.56	7.99	2.80	1.34	0.62	2.06	45.23
1943	2.57	1.54	5.94	2.63	2.41	0.87	0.99	0.53	2.57	2.07	2.83	5.69	30.64
1944	6.35	5.57	7.37	5.52	9.21	0.94	1.35	5.05	1.22	0.03	4.47	8.98	56.06
1945	4.05	5.02	11.99	6.47	3.45	3.55	5.68	1.26	2.81	6.90	2.83	3.66	57.67
1946	11.53	5.39	5.55	5.32	9.47	5.18	4.58	3.44	1.54	2.47	6.37	3.69	64.53
1947	3.57	3.60	6.19	6.40	2.84	2.02	0.84	2.77	3.52	1.76	4.93	5.84	44.28
1948	4.39	4.14	3.39	2.80	6.92	1.16	2.58	1.06	0.41	1.47	7.03	2.75	38.10
1949	7.81	3.72	2.94	2.86	1.63	2.16	4.37	1.06	3.74	14.02	0.37	5.20	49.88
1950	5.69	4.30	2.18	5.95	6.85	2.72	6.45	4.11	3.84	3.08	1.91	0.80	47.88
1951	5.43	2.72	3.28	1.82	1.10	2.81	3.30	0.47	5.52	1.64	2.43	7.23	37.75
1952	4.22	5.76	4.44	5.34	6.71	0.74	4.26	1.12	0.80	0.04	3.98	5.24	42.64
1953	4.26	3.98	4.61	9.82	8.35	1.30	3.03	1.22	1.06	1.57	2.16	5.20	46.56
1954	3.82	0.90	1.49	3.93	7.96	1.88	1.01	0.92	2.27	2.88	4.24	3.66	34.96
1955	3.44	4.43	3.20	4.78	9.64	2.67	6.17	6.83	1.09	1.93	0.83	2.42	47.23
1956	3.68	4.58	4.47	4.51	3.85	3.11	0.30	2.25	0.17	2.05	3.50	1.54	34.01
1957	5.07	4.05	6.55	11.19	3.45	8.37	3.26	1.75	4.17	6.78	9.49	3.10	67.43
1958	4.18	1.98	3.15	7.78	2.89	6.86	4.13	2.22	8.58	0.55	3.75	0.68	46.75
1959	1.17	4.79	2.82	3.58	3.23	3.35	3.29	2.13	1.64	3.90	2.94	6.18	39.02
1960	3.08	4.49	4.04	3.39	1.88	7.35	2.88	4.99	4.98	2.34	2.99	8.10	48.51
1961	3.79	3.88	6.15	1.70	1.46	12.39	3.95	2.26	5.75	3.51	5.16	7.50	57.50
1962	4.26	2.12	3.28	5.78	1.22	4.70	0.60	3.96	2.57	1.26	3.52	2.35	35.62
1963	1.46	2.42	0.91	3.53	2.25	2.65	1.00	3.74	2.36	0.00	6.72	2.99	30.03
1964	2.57	2.74	4.24	7.27	1.41	1.87	3.15	4.74	2.51	0.64	1.65	2.55	32.31
1965	3.77	6.51	3.39	2.26	4.40	3.18	1.49	1.82	6.55	0.36	1.20	6.29	42.22
1966	4.22	3.45	0.56	8.62	3.78	2.05	0.58	1.71	3.27	1.62	0.97	3.63	33.86
RECORD MEAN	4.15	3.81	4.24	4.75	4.31	3.34	3.35	2.62	2.86	2.83	3.78	4.55	44.39

TOTAL SNOWFALL

Season	July	Aug	Sept.	Oct.	Nov	Dec.	Jan	Feb.	Mar.	Apr	May	June	Total

Record mean values above (not adjusted for instrument location changes listed in the Station Location table) are means for the period beginning in 1875 for temperature and 1872 for precipitation.

A horizontal line drawn on the above tables indicates a break in the data sequence due to a change in instrument exposure or a station move (see Station Location table).

STATION LOCATION

Location	Occupied from	Occupied to	Airline distance and direction from previous location	Latitude North	Longitude West	Elevation above Sea level: Ground at temperature site	Elevation above Ground: Wind instruments	Extreme thermometers	Psychrometer	Telepsychrometer	Tipping bucket rain gage	Weighing rain gage	8" rain gage	Hygrothermometer	Pyrheliometer	Remarks
CITY OFFICE																
Brooks House	9- 2-71	10- 3-71		32° 30'	93° 45'											
Southern Hotel	10- 3-71	12-16-71		32° 30'	93° 45'											
National Hotel Milam Street	12-16-71	10- 4-74		32° 30'	93° 45'	192	57	22					24			
Begel's Building, Cor. Texas & Marshall Streets	10- 4-74	8-28-75		32° 30'	93° 45'			38	38		55		55			
Martin Building, Corner Milam & Martin's Alley	8-28-75	12- 1-80		32° 30'	93° 45'	187	47	24	24		35		55			
Rendall's Building 207 Milam Street	12- 1-80	4-17-88	100 ft. E	32° 30'	93° 44'			33	33				40			
P. O. & Customs House Texas & Marshall Streets	4-17-88	5- 1-10	800 ft. SSE	32° 30'	93° 40'	196	84	77	77		74		74			
Majestic Theatre Bldg. Milam & McNeil Streets	5- 1-10	2- 1-13	500 ft. SSW	32° 30'	93° 40'		74	68	68		59		59			
P. O. Building Texas & Marshall Sts.	2- 1-13	7-14-31	800 ft. ENE	32° 30'	93° 40'	196	93	77	77		70		70			
Slattery Building Texas & Marshall Sts	7-14-31	8-19-32	75 ft. S	32° 30'	93° 40'	196	227	204	204		197		197			
Federal Building Texas & Marshall Sts.	8-19-32	10- 6-41	78 ft. N	32° 30'	93° 40'	196	227	92	92		90		90			Wind instruments and sunshine recorder were retained on Slattery Building because of poor exposure at Post Office Building site.
AIRPORT STATION																
Admn. Bldg., Shreveport Downtown Airport	10-7-41	7-6-52	2 mi. NNW	32° 33'	93° 46'	174	64	5	5		3		3			
Greater Shreveport Municipal Airport	7- 6-52	Present	7.6 mi. SSW	32° 28'	93° 49'	b254	d20	6	5		3	a5	3	c5		Hygrothermometer commissioned 12-17-60. a - 4 feet to 8-18-66. b - 252 feet to 9-2-66. c - moved 750 feet westward 9-2-66. d - 55 feet to 11-17-66.

Requests for additional information should be directed to the Weather Bureau Office for which this summary was issued.

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USCOMM-ESSA-ASHEVILLE - 650

LOCAL CLIMATOLOGICAL DATA
ANNUAL SUMMARY WITH COMPARATIVE DATA, 1966

TEXARKANA, ARKANSAS

NARRATIVE CLIMATOLOGICAL SUMMARY

Texarkana is located in northeast Texas and southwest Arkansas astride the Texas-Arkansas state line, with the Weather Bureau station at the Municipal Airport on the Arkansas side of the state line. In this location it is more or less protected by the Ozark Mountains from the more severe winds and cold waves that come down out of Canada. Thus, the normal winters in this area are relatively mild.

The spring and autumn months are mild with cool nights and warm days. Summers are usually rather mild, but the high humidity of this area, where the warm moist winds from the gulf meet the cooler air from the land areas, causes high temperatures to be more oppressive than they would be in drier air. Summer nights are frequently uncomfortable, partly because of the high humidity, but primarily because the wind becomes calm, or almost so, in the late afternoon and remains so during the night.

The average growing season for this locality is 238 days. Mean date of the last freezing temperature in the spring is March 19, while mean date of first fall occurrence is November 11. Snowfall in Texarkana is usually very light with only an occasional fairly heavy fall.

Thunderstorms are frequent from May until September, but with only limited hailstorm damage recorded during the period of record. On the other hand, several small tornadoes have occurred.

U.S. DEPARTMENT OF COMMERCE
JOHN T. CONNOR, Secretary
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
ROBERT M. WHITE, Administrator
ENVIRONMENTAL DATA SERVICE

LATITUDE 33° 27' N
LONGITUDE 94° 00' W
ELEVATION (ground) 372 Feet

METEOROLOGICAL DATA FOR THE CURRENT YEAR

TEXARKANA, ARKANSAS
MUNICIPAL AIRPORT
1966

Month	Temperature: Averages: Daily maximum	Daily minimum	Monthly	Extremes: Highest	Date	Lowest	Date	Degree days	Precipitation: Total	Greatest in 24 hrs	Date	Snow, Sleet: Total	Greatest in 24 hrs	Date	Relative humidity: Midnight CST	6:00 A.M. CST	Noon CST	6:00 P.M. CST	Wind: Resultant: Direction	Speed	Average speed	Fastest mile: Speed	Direction	Date	Percent of possible sunshine	Average sky cover sunrise to sunset	Number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Maximum: 90 and above	32 and below	Minimum: 32 and below	0 and below
JAN	49.0	32.4	40.7	69	1	9	30	749	4.03	1.32	28-29	6.4	2.8	24	74	81	67	68	06	1.8	7.0					6.8	8	3	20	10	3	2	1	0	3	15	0
FEB	55.6	35.8	45.7	70	7	21	3	534	2.63	0.94	9-10	7.0	7.0	22-23	76	83	63	62	18	0.6	7.3					5.8	11	4	13	10	2	0	1	0	0	13	0
MAR	68.3	44.3	56.3	88	31	25	7	281	3.75	0.37	12-13	0.0	0.0		61	73	46	42	22	2.5	7.8					5.1	12	7	12	6	0	1	1	0	0	*	0
APR	75.5	52.9	64.2	88	12	36	5	82	16.65	5.11	25-26	0.0	0.0		72	83	60	58	18	3.3	9.0					5.9	10	6	14	12	0	12	0	0	0	0	0
MAY	80.9	58.4	69.7	89	22	44	3	22	1.76	0.95	12-13	0.0	0.0		83	91	63	61	16	2.9	6.8					6.3	6	12	13	8	0	5	0	0	0	0	0
JUN	89.2	65.0	77.1	98	29	51	1	0	0.78	0.57	13	0.0	0.0		76	88	52	53	16	3.5	6.5					4.5	16	8	6	5	0	2	0	15	0	0	0
JUL	94.0	74.0	84.0	101	19	69	26	0	5.58	1.63	30-1	0.0	0.0		82	90	60	63	19	2.7	5.9					4.8	16	7	8	6	0	8	0	27	0	0	0
AUG	88.2	69.[illegible]	78.7	96	8	57	25	0	8.62	3.57	10-11	0.0	0.0		87	94	64	68	14	2.0	5.9					6.2	7	9	15	15	0	8	1	14	0	0	0
SEP	82.5	64.3	73.4	91	3	55	22+	0	2.74	1.40	9-10	0.0	0.0		88	94	68	72	06	0.8	6.4					5.3	[illegible]	12	9	9	0	4	*	5	0	0	0
OCT	74.3	50.6	62.5	88	14+	38	20	124	2.55	2.13	4	0.0	0.0		78	87	52	53	14	2.1	7.8					3.3	19	5	7	3	0	2	0	0	0	0	0
NOV	70.0	48.4	59.2	90	6	23	3	212	2.30	1.77	9	0.0	0.0		71	85	56	58	19	3.2	8.9					5.3	[illegible]	11	9	4	0	2	2	0	0	2	0
DEC	53.6	35.9	44.8	80	7	17	24	636	5.77	2.87	27	T	T	28+	82	87	75	72	17	1.2	8.7					7.4	7	1	23	14	0	5	7	0	0	14	0
YEAR	73.4	52.6	63.0	101	JUL. 19	9	JAN. 30	2640	56.16	5.11	APR. 25-26	13.4	7.0	FEB. 22-23	78	88	61	62	16	1.6	7.4					5.6	131	85	149	97	5	51	1[illegible]	61	3	48	0

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes ø: Record highest	Year	Record lowest	Year	Normal degree days	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity: Midnight CST	6:00 A.M. CST	Noon CST	6:00 P.M. CST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms $	Heavy fog $	Temperatures: Max: 90 and above	32 and below	Min: 32 and below	0 and below
(a)	(b)	(b)	(b)	7		7		(b)	(b)	24		24		24		24	24		24		2	2	2	2	10	7					7	2	2	2	24	24	24	24	2	2	2	2
J	54.9	35.[illegible]	45.1	76	1965	9	1966	626	4.84	9.55	1949	0.78	1959	5.79	1957	1.5	7.5	1962	7.5	1962	72	81	64	65	7.9	NE					6.[illegible]	10	4	17	1[illegible]	1	2	3	0	2	13	0
F	58.8	39.1	48.5	72	1965	20	1965	468	4.0[illegible]	9.44	1950	1.01	1947	3.85	1950	0.8	7.0	1966	7.0	1966	72	79	59	57	8.5	NE					5.8	10	5	13	1[illegible]	*	3	3	0	0	12	0
M	65.8	44.[illegible]	54.9	88	1966	18	1965	350	4.74	15.33	1945	0.75	1966	5.36	1945	0.1	1.5	1965	1.4	1965	66	75	53	50	8.9	WNW					5.1	9	7	15	11	*	6	2	0	0	5	0
A	74.8	53.[illegible]	63.9	88	1966+	36	1966	105	5.30	16.65	1966	1.05	1960	5.11	1966	0.0	0.0		0.0		71	82	58	54	9.4	SSW					5.5	11	6	13	1[illegible]	0	7	1	0	0	0	0
M	82.2	61.0	71.6	89	1966	44	1966	0	4.90	12.05	1946	1.76	1966	3.77	1947	0.0	0.0		0.0		83	89	64	66	8.1	SSW					6.5	5	1[illegible]	15	9	0	8	1	0	0	0	0
J	89.9	68.9	79.4	98	1966	51	1966	0	3.89	1[illegible].31	1945	0.30	1953	6.55	1945	0.0	0.0		0.0		81	89	59	59	6.[illegible]	SSW					4.9	14	8	8	7	0	7	1	13	0	0	0
J	93.3	71.9	82.6	101	1966	60	1965	0	3.84	7.69	1953	0.39	1947	3.14	1953	0.0	0.0		0.0		82	90	59	6[illegible]	5.3	SW					4.5	15	9	[illegible]	7	0	9	*	27	0	0	0
A	93.4	71.8	82.6	106	1965	57	1966	0	3.07	8.62	1966	0.16	1954	3.57	1966	0.0	0.0		0.0		85	92	59	52	6.3	SSW					5.1	11	11	[illegible]	7	0	7	1	[illegible]	0	0	0
S	88.0	65.0	76.5	98	1965	47	1965	0	2.7[illegible]	7.79	1964	0.04	1952	5.[illegible]4	1964	0.0	0.0		0.[illegible]		85	93	65	73	6.8	NE					4.9	12	10	[illegible]	7	0	5	1	11	0	0	0
O	78.5	53.7	66.1	92	1965	29	1965	78	2.98	9.78	1947	T	1963	4.56	1957	0.0	0.0		[illegible]		78	87	51	61	6.5	NE					3.5	19	4	[illegible]	5	0	3	2	1	0	0	0
N	64.[illegible]	42.4	53.[illegible]	88	1965	22	1964	345	4.33	9.91	1946	0.22	1949	4.09	1944	0.1	1.5	1957	1.[illegible]	1957	74	85	58	6[illegible]	7.7	NE					[illegible]	8	8	[illegible]	[illegible]	*	3	2	0	0	2	0
D	56.[illegible]	37.1	46.9	80	1966+	17	1966	561	4.55	9.45	1944	0.19	1954	3.64	1959	0.3	5.3	1963	5.0	1963	83	87	[illegible]	[illegible]	8.1	NE					5.8	14	1	2[illegible]	8	*	2	3	0	0	11	0
YR	75.1	53.[illegible]	64.[illegible]	101	JUL. 1966	9	JAN. 1966	2533	49.[illegible]9	16.65	APR. 1966	T	OCT. 1963	6.55	JUN. 1945	2.8	7.5	JAN. 1962	7.5	JAN. 1962	77	86	60	61	7.6	NE					5.[illegible]	135	83	147	98	1	63	18	7[illegible]	2	44	0

ø For period September 1964 through the current year.

Means and extremes in the above table are from the existing location. Annual extremes have been exceeded at other locations as follows: Highest temperature 117 in August 1936; lowest temperature -3 in February 1951; maximum monthly precipitation 18.28 in October 1919.

(a) Length of record, years.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Degree day totals are the sums of the negative departures of average daily temperatures from 65°F. Sleet was included in snowfall totals beginning with July 1948. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3; partly cloudy days 4-7; and cloudy days 8-10 tenths.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 East, 18 South, 27 West, 36 North, and 00 Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

$ Fog and thunderstorm data may be incomplete; the station has not always operated 24 hours daily.

AVERAGE TEMPERATURE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1931	45.4	50.3	48.9	60.2	67.0	79.7	83.4	78.8	79.7	70.4	60.0	50.5	64.5
1932	48.4	55.1	52.4	65.8	71.2	81.2	83.6	83.6	76.4	64.1	50.1	45.2	64.8
1933	53.4	45.4	56.4	63.8	73.6	79.0	82.2	80.8	80.0	64.4	56.2	53.5	65.7
1934	47.2	46.5	52.8	65.3	71.0	80.8	85.2	87.6	75.6	70.3	57.4	45.8	65.4
1935	47.2	48.8	61.2	63.5	68.8	76.6	82.6	84.2	73.8	66.1	52.7	41.7	63.9
1936	41.1	40.8	60.6	62.6	73.2	82.8	84.0	88.6	82.9	63.8	52.0	50.0	65.2
1937	45.7	49.8	52.4	64.5	73.4	80.6	81.4	84.0	77.4	64.6	52.6	47.9	64.5
1938	48.0	55.4	64.7	64.6	73.4	78.9	83.9	85.7	79.0	71.3	55.1	48.8	67.4
1939	50.3	49.3	59.0	64.0	74.4	82.9	86.5	85.6	84.3	69.5	53.7	51.9	67.6
1940	36.0	48.0	57.2	64.9	69.8	77.2	80.3	79.5	75.2	69.8	54.0	51.8	63.6
1941	49.6	46.2	52.2	66.4	74.0	77.8	81.6	82.8	77.8	71.2	53.0	48.8	65.1
1942	43.2	46.0	56.4	69.4	71.6	80.3	83.2	81.5	73.4	65.6	58.5	46.8	64.7
1943	44.9	51.1	50.5	67.1	74.2	82.2	83.3	85.8	74.6	65.0	53.5	44.6	64.7
1944	45.8	51.8	55.0	63.8	71.6	81.8	84.0	82.8	76.0	66.8	56.0	42.6	64.8
1945	43.8	48.5	61.4	64.8	69.4	78.4	80.2	80.8	77.2	63.7	57.7	42.1	64.0
1946	43.8	51.1	60.0	68.0	69.3	77.6	81.9	80.9	74.5	66.4	56.0	52.1	65.1
1947	45.8	41.0	48.8	65.0	70.0	79.0	81.2	85.1	77.0	70.9	51.0	48.2	63.6
1948	37.3	46.4	54.4	68.6	72.0	80.6	83.4	81.8	75.9	64.3	53.6	49.6	64.0
1949	45.9	50.4	55.5	63.1	75.0	80.2	82.8	79.9	73.2	65.7	57.1	50.0	64.9
1950	53.2	51.8	53.6	61.8	[illegible]	78.2	78.8	78.8	72.1	68.9	52.2	43.2	63.8
1951	45.3	48.4	55.3	61.7	71.6	78.6	83.3	86.0	75.9	66.4	49.9	48.8	64.3
1952	52.7	52.3	53.4	60.6	71.1	82.5	83.4	83.3	75.8	60.1	52.5	45.6	64.5
1953	49.3	49.3	60.9	61.4	72.3	84.6	81.3	80.8	76.6	68.0	52.5	44.3	65.1
1954	46.8	54.8	55.2	69.0	67.0	80.9	86.8	87.2	79.8	67.2	54.1	47.9	66.4
1955	45.0	47.5	57.1	67.3	74.1	76.0	82.5	80.5	77.8	65.3	53.6	45.7	64.4
1956	43.9	51.6	55.0	62.6	75.4	79.0	84.7	84.1	77.2	68.7	52.6	53.0	65.7
1957	43.4	55.1	53.0	64.0	73.4	78.9	83.3	81.7	74.1	62.1	53.7	51.5	64.5
1958	43.5	43.1	50.3	62.1	72.7	79.5	82.7	81.4	76.8	64.0	56.8	42.9	63.0
1959	43.6	48.8	54.5	61.9	74.9	77.5	80.7	81.7	77.2	65.5	49.2	49.6	63.7
1960	44.0	42.3	45.9	66.0	70.1	79.4	82.3	82.3	77.4	67.3	55.5	42.6	62.9
1961	41.3	50.7	58.5	61.7	70.8	75.1	79.8	79.0	75.2	65.3	52.7	45.1	63.0
1962	40.4	53.7	52.1	62.3	75.6	77.9	83.1	83.2	75.8	68.3	53.2	46.0	64.3
1963	37.4	44.5	60.3	66.9	73.3	81.2	82.3	83.5	76.1	72.3	57.7	38.6	64.5
1964	45.3	45.0	55.4	67.0	73.9	79.9	84.9	82.5	75.0	62.4	58.4	47.7	64.8
1965	47.9	47.2	47.5	69.8	74.1	78.0	82.9	81.4	76.0	64.5	61.1	50.9	65.1
1966	40.7	45.7	56.3	64.2	69.7	77.1	84.0	78.7	73.4	62.5	59.2	44.8	63.0
RECORD MEAN	45.3	49.0	55.2	64.5	72.0	79.6	83.0	82.7	76.8	66.5	54.9	47.3	64.7
MAX	55.5	59.8	66.6	76.0	82.9	90.5	94.3	94.3	88.8	79.3	66.6	57.3	76.0
MIN	35.1	38.2	43.8	53.0	61.0	68.6	71.6	71.0	64.7	53.6	43.1	37.2	53.4

TOTAL DEGREE DAYS

TEXARKANA, ARKANSAS
MUNICIPAL AIRPORT

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1930-31	0	0	4	164	367	684	601	414	501	167	56	0	2958
1931-32	0	0	0	58	194	451	518	291	422	51	0	0	1985
1932-33	0	0	0	99	452	598	357	561	282	91	6	0	2446
1933-34	0	0	0	71	280	367	551	524	390	59	9	0	2251
1934-35	0	0	0	18	250	593	555	460	177	107	37	0	2197
1935-36	0	0	6	61	384	721	744	715	149	163	0	0	2943
1936-37	0	0	6	110	406	468	598	437	393	106	14	1	2539
1937-38	0	0	4	91	386	527	522	277	94	115	10	0	2026
1938-39	0	0	2	35	332	511	454	440	203	108	0	0	2085
1939-40	0	0	1	72	365	404	895	499	256	108	5	0	2585
1940-41	0	0	10	19	331	409	481	517	404	45	0	0	2216
1941-42	0	0	0	57	349	495	618	463	182	36	9	0	2209
1942-43	0	0	41	63	242	577	629	390	457	63	5	0	2467
1943-44	0	0	0	94	359	641	586	388	320	96	32	0	2516
1944-45	0	0	0	55	296	695	661	466	169	87	45	0	2474
1945-46	0	0	0	103	267	708	659	389	175	41	11	0	2353
1946-47	0	0	3	67	290	407	595	675	503	70	8	0	2618
1947-48	0	0	5	12	419	521	860	542	367	42	5	0	2773
1948-49	0	0	2	88	354	494	599	407	296	128	0	0	2368
1949-50	0	0	16	102	258	471	389	373	365	149	3	1	2127
1950-51	0	0	7	16	404	676	603	463	306	155	7	0	2637
1951-52	0	0	0	73	455	513	397	362	367	155	11	0	2333
1952-53	0	0	0	201	396	595	480	435	164	137	30	0	2438
1953-54	0	0	0	74	370	635	556	284	337	32	67	0	2355
1954-55	0	0	0	111	321	519	613	493	300	59	0	1	2417
1955-56	0	0	0	98	395	600	652	393	334	128	7	0	2607
1956-57	0	0	0	29	377	390	665	283	363	110	16	0	2233
1957-58	0	0	0	132	348	417	660	609	449	121	13	0	2749
1958-59	0	0	4	110	263	678	659	454	327	147	1	0	2643
1959-60	0	0	0	81	489	472	648	656	592	57	37	0	3032
1960-61	0	0	0	53	295	686	729	397	228	166	19	7	2580
1961-62	0	0	4	90	371	611	756	314	395	133	1	0	2675
1962-63	0	0	0	56	346	579	848	569	186	47	23	0	2654
1963-64	0	0	2	12	235	811	602	574	299	49	2	0	2586
1964-65	0	0	10	123	237	534	525	494	538	38	0	0	2499
1965-66	0	0	8	100	136	437	749	534	281	82	22	0	2349
1966-67	0	0	0	124	212	636							

TOTAL PRECIPITATION

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1931	1.81	4.00	4.73	2.40	1.94	3.68	8.04	3.55	0.90	2.14	7.72	7.65	48.56
1932	10.00	6.13	6.41	2.73	0.84	3.92	6.23	1.12	0.87	2.30	1.42	8.72	50.69
1933	4.93	2.99	3.45	4.43	3.03	0.72	7.70	2.68	3.30	5.17	1.22	6.94	46.56
1934	1.63	2.59	5.98	5.42	2.86	4.22	2.25	0.22	3.35	0.35	7.58	4.89	41.34
1935	8.12	3.69	3.68	5.16	6.59	5.71	1.05	0.63	3.23	4.56	5.52	3.65	51.59
1936	1.87	1.28	1.71	1.59	4.51	T	2.66	1.33	2.75	3.83	2.66	5.18	28.39
1937	14.97	3.69	4.70	3.99	3.42	5.66	3.21	5.94	0.32	3.92	9.19	8.96	67.97
1938	9.80	3.98	4.74	5.08	2.65	6.92	2.70	1.51	3.14	1.84	4.83	4.20	51.39
1939	6.18	8.49	3.85	3.97	1.16	3.27	0.99	1.03	0.99	1.43	7.79	3.08	42.23
1940	1.38	2.92	2.70	10.35	6.41	6.17	15.19	4. 3	0.25	1.90	9.40	4.43	65.43
1941	2.62	3.73	6.34	9.26	3.87	4.62	6.49	5.20	4.08	4.34	2.77	6.22	59.54
1942	2.35	1.39	4.78	9.90	3.72	5.84	0.70	7.66	3.75	2.13	0.64	4.71	47.57
1943	1.64	1.18	3.87	3.11	6.77	2.54	2.25	0.20	2.35	3.58	0.62	3.55	31.66
1944	4.14	8.19	6.27	8.00	6.89	2.73	3.67	8.49	1.86	1.10	8.66	9.45	66.45
1945	2.29	6.61	15.33	4.04	3.49	10.31	4.05	1.63	5.08	1.93	3.64	3.29	61.69
1946	8.17	4.97	5.49	5.90	12.05	3.34	2.98	2.85	0.89	2.54	9.91	1.91	61.00
1947	2.45	1.01	3.63	2.97	6.80	3.11	0.39	3.11	3.08	2.50	6.88	7.17	43.10
1948	3.21	5.12	5.67	3.99	6.95	1.50	3.71	2.93	0.23	2.46	4.07	3.07	42.91
1949	9.55	2.85	4.23	2.40	1.93	3.42	5.31	1.59	3.96	9.78	0.22	3.84	49.08
1950	7.85	9.44	5.82	4.15	11.42	2.25	5.25	4.90	7.26	1.74	0.48	0.19	60.75
1951	4.47	4.25	2.54	5.56	2.98	5.95	3.65	1.18	5.32	3.48	2.03	2.38	43.79
1952	2.28	2.15	6.13	6.55	3.92	2.23	2.35	2.50	0.04	0.33	9.22	4.10	41.80
1953	5.47	1.83	5.35	7.61	8.12	0.30	7.69	2.90	0.64	0.78	2.54	3.81	47.04
1954	4.81	1.92	1.28	3.92	9.26	0.59	1.94	0.16	1.56	5.49	1.40	3.96	36.29
1955	2.38	4.45	6.03	4.07	4.73	1.49	4.71	4.23	6.83	0.88	1.15	1.75	42.70
1956	2.23	5.69	2.82	3.25	3.03	3.67	1.98	2.41	0.13	1.47	3.87	0.89	31.44
1957	7.67	3.56	5.36	10.64	6.91	6.84	1.95	2.10	4.18	7.88	9.65	2.93	69.67
1958	4.49	1.25	3.41	14.00	2.48	6.21	2.29	7.19	5.73	3.25	2.93	0.52	53.75
1959	0.78	5.68	3.41	3.56	4.11	5.57	5.55	1.56	1.70	3.18	1.91	7.52	44.53
1960	5.64	4.52	2.35	1.05	4.12	3.85	1.32	7.10	4.24	3.05	0.99	7.47	45.70
1961	1.46	4.05	4.67	1.49	2.54	7.54	6.68	2.17	5.74	2.32	3.79	7.87	55.32
1962	6.22	5.52	3.22	3.40	2.30	4.90	3.14	2.12	4.54	4.57	3.29	1.16	44.38
1963	1.48	2.29	2.38	6.22	4.60	5.00	4.52	3.00	0.57	T	4.22	3.63	37.91
1964	0.83	2.74	4.03	10.06	2.71	2.75	3.09	4.47	7.79	0.47	3.51	3.07	45.52
1965	4.51	9.38	3.23	1.07	5.19	3.41	3.02	4.05	3.27	0.40	1.27	2.41	41.21
1966	4.03	2.63	0.75	16.65	1.76	0.78	5.58	8.62	2.74	2.55	2.30	5.77	54.16
RECORD MEAN	4.50	3.83	4.58	5.56	4.67	3.76	3.79	3.50	2.93	3.27	3.91	4.36	48.66

TOTAL SNOWFALL

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1942-43	0.0	0.0	0.0	0.0	0.0	T	T	0.0	0.0	0.0	0.0	0.0	T
1943-44	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	1.9
1944-45	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	0.0	T
1945-46	0.0	0.0	0.0	0.0	0.0	T	6.1	T	0.0	0.0	0.0	0.0	6.1
1946-47	0.0	0.0	0.0	0.0	0.0	T	T	T	T	0.0	0.0	0.0	T
1947-48	0.0	0.0	0.0	0.0	0.0	0.0	2.2	1.8	T	0.0	0.0	0.0	4.0
1948-49	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	4.5
1949-50	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	T
1950-51	0.0	0.0	0.0	0.0	T	T	4.3	0.0	0.0	0.0	0.0	0.0	4.3
1951-52	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	T	0.0	0.0	0.0	T
1952-53	0.0	0.0	0.0	0.0	T	T	T	0.0	0.0	0.0	0.0	0.0	T
1953-54	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	T	0.0	0.0	0.0	0.6
1954-55	0.0	0.0	0.0	0.0	0.0	T	0.0	T	T	0.0	0.0	0.0	T
1955-56	0.0	0.0	0.0	0.0	T	T	1.0	0.0	T	0.0	0.0	0.0	1.0
1956-57	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	T
1957-58	0.0	0.0	0.0	0.0	1.5	0.0	0.0	1.6	0.0	0.0	0.0	0.0	3.1
1958-59	0.0	0.0	0.0	0.0	0.0	1.1	T	T	0.0	0.0	0.0	0.0	1.1
1959-60	0.0	0.0	0.0	0.0	0.0	0.0	0.2	4.1	T	0.0	0.0	0.0	4.3
1960-61	0.0	0.0	0.0	0.0	0.0	T	1.9	T	0.0	0.0	0.0	0.0	1.9
1961-62	0.0	0.0	0.0	0.0	0.0	T	7.5	T	0.1	0.0	0.0	0.0	7.6
1962-63	0.0	0.0	0.0	0.0	0.0	T	0.2	0.5	T	0.0	0.0	0.0	0.7
1963-64	0.0	0.0	0.0	0.0	0.0	5.3	0.3	0.0	0.0	0.0	0.0	0.0	5.6
1964-65	0.0	0.0	0.0	0.0	0.0	0.1	0.0	3.0	1.5	0.0	0.0	0.0	4.6
1965-66	0.0	0.0	0.0	0.0	0.0	0.0	6.4	7.0	0.0	0.0	0.0	0.0	13.4
1966-67	0.0	0.0	0.0	0.0	0.0	T							

Record mean values above (not adjusted for instrument location changes listed in the Station Location table) are means for the period beginning in 1912.

A horizontal line drawn on the above tables indicates a break in the data sequence due to a change in instrument exposure or a station move (see Station Location table). Data are from Cooperative locations through July 1942 and from Airport locations thereafter.

STATION LOCATION

Location	Occupied from	Occupied to	Airline distance and direction from previous location	Latitude North	Longitude West	Elevation above: Sea level: Ground at temperature site	Ground: Wind instruments	Extreme thermometers	Psychrometer	Telepsychrometer	Tipping bucket rain gage	Weighing rain gage	8" rain gage	Hygrothermometer	Dew cell	Remarks
COOPERATIVE																
Exact location unknown	4- 7-83	6-30-11		33 24'	94 02'	320										
1217 Hazel Street	7- 1-11	3-31-35		33 24'	94 02'	320										
2024 Magnolia Street	4- 1-35	7-31-42	1/3 mi. N	33 25'	94° 02'	332										
AIRPORT STATION																
Texarkana Municipal Airport, Admn. Bldg 4 mi. NE of P. O.	4- 1-31	4-25-42		33° 27'	94° 00'	361	32	6	6			5	4			
Texarkana Municipal Airport, Admn. Bldg.	4-25-42	9-1-64		33° 27'	94° 00'	361	a27	6	6	b6		4	4		b5	a - 32 ft. to 6-12-59. b - Added 12-9-54.
Administration Building Municipal Airport	9- 1-64	Present	(A)	33° 27'	94° 00'	372	20	6				4	4	c5		(A) Instrument changes and relocations. Office not moved. c - Commissioned 2400 ft. NE of thermometer site.

Requests for additional information should be directed to the Weather Bureau Office for which this summary was issued.

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RED RIVER BELOW DENISON DAM
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS
COMPREHENSIVE BASIN STUDY

APPENDIX III

HYDROLOGY, SURFACE AND GROUND WATER, AND GEOLOGY

Prepared by
U. S. Army Corps of Engineers
and the
U. S. Department of the Interior, Geological Survey

June 1968

SUMMARY

This appendix, prepared as part of the Red River below Denison Dam Comprehensive Basin Study interagency report, presents information on surface and ground water in the study area and description of the geology of the basin as it pertains to water availability.

The study area contains large supplies of good-quality water that can be developed for nearly any desired use. Approximately two-thirds of the basin is underlain by fresh-water-bearing aquifers that are capable of yielding as much as several hundred gallons of water per minute to wells. In some locations, principally in the Red River alluvium in Arkansas and Louisiana, yields as high as 1,700 gallons per minute are achieved. As much as 800 million gallons per day of water is available from the aquifers in the basin.

Development of the ground-water resources should follow testing programs and should be based on a consideration of the depth of fresh-water occurrence, thickness and permeability of the water-bearing sands, water-level fluctuations, and expected yields.

Large surface-water supplies are also available. However, with the exception of a few streams, such as Loggy, Saline, and Black Lake Bayous, storage facilities will be required to provide continuous supplies of water.

The collection of runoff and streamflow data began in the study area as early as 1872 and voluminous records are available. Of course, these records reflect the influence of changing conditions due to man-made improvements. Historical records indicate that subsequent to 1900, flooding on Red River has occurred at least once in each succeeding decennium and that flooding on one or more of the tributaries occurs more frequently.

Included in this appendix is the determination of design stages and discharges for the Corps of Engineers proposed navigation and bank stabilization improvements under future regulated conditions with all authorized reservoirs in place. Also contained in this appendix is the derivation of the "standard project flood" for the basin, which flood represents an estimate of flood discharges that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the basin.

APPENDIX III

HYDROLOGY, SURFACE AND GROUND WATER, AND GEOLOGY

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FIGURES (cont'd)

APPENDIX III

HYDROLOGY, SURFACE AND GROUND WATER, AND GEOLOGY

CHAPTER I - INTRODUCTION

1. PURPOSE

The purpose of this appendix is to develop information on the geologic features and hydrologic environment of the lower Red River Basin as a basis for evaluating the water resource needs of the basin and formulating a comprehensive plan of development and management of these resources.

2. SCOPE

This appendix presents the general geology of the basin as it pertains to the occurrence of ground water, basic hydrologic data on the thickness and extent of the principal water-bearing formations, as well as extremes, averages, and distribution of surface runoff and streamflows. Hydrologic studies presented herein include: estimates of the quantity of ground water available and yields of wells that might be drilled; evaluation of flow characteristics of streams and their relation to ground water availability; development of hydrographs for each drainage subbasin; development and evaluation of design criteria for the leveed floodway of the Red River considering the effect of the Corps of Engineers' proposed navigation and bank stabilization improvements; analyses of sedimentation phenomena in Red River; and determination of the standard project flood for the basin.

3. NATURE OF AVAILABLE HYDROLOGIC INFORMATION

This appendix is based on data collected during previous geologic and hydrologic studies. Major sources of information pertinent to this study were extracted from various published periodicals, bulletins, circulars, and reports of the U. S. Geological Survey, U. S. Weather Bureau, U. S. Army Corps of Engineers, and State agencies in Arkansas, Louisiana, Oklahoma, and Texas. Additional sources were publications of other Federal agencies, agency manuals, handbooks, and other guides. Much of the material examined was utilized in a way that would make direct reference inappropriate. However, throughout the appendix where data, methods, or criteria are used, major source data are indicated.

4. ACKNOWLEDGMENTS

This appendix was prepared as a joint undertaking by the U. S. Army Corps of Engineers Districts in New Orleans, Louisiana, and Tulsa, Oklahoma, and the U. S. Geological Survey. Major contributions

of the Geological Survey include all of Chapters II, III, V, and VIII, and parts of Chapter IX. The report of the Geological Survey was prepared by A. H. Ludwig, Little Rock, Arkansas.

CHAPTER II - DESCRIPTION OF BASIN

5. LOCATION AND EXTENT

The Red River Basin below Denison Dam, exclusive of the Ouachita-Black River Basin, covers 29,500 square miles. It includes all or parts of 50 counties and parishes in southwestern Arkansas, northwestern Louisiana, southeastern Oklahoma, and northeastern Texas (Fig. 1). The lower Red River Basin abuts the Arkansas River Basin on the north, the Ouachita River Basin on the east, the Sabine River Basin on the south, and the basin of the Red River above Denison Dam on the west.

The area lies between latitude 31° and 35° N. and longitude 92° and 97° W.

6. CLIMATE

The climate of the lower Red River Basin varies in classification from moist-subhumid to humid; i.e., precipitation equals or exceeds potential evaporation.

Average annual precipitation ranges from 37 inches at Denison Dam to about 59 inches at Alexandria, La. Annual normals by section are 40.2 inches for southeast Oklahoma, 45.6 inches for northeast Texas, 49.6 inches for southwest Arkansas, and 53.0 inches for northwest Louisiana. Monthly normal rainfall ranges from 2.6 inches in September to 5.7 inches in May. A maximum rainfall of 109.38 inches occurred at Clarksville, Texas, in 1873 and a minimum of 12.72 inches at Bonham, Texas, in 1910. Although precipitation normally is well distributed throughout the year, droughts of short duration are fairly frequent during the growing season. Snowfall occurs about once every 2 to 3 years, averaging 4 inches in southern Oklahoma, 2.4 inches in northeast Texas, 3.1 inches in southwest Arkansas, and 1.7 inches in northwest Louisiana.

The average annual air temperature ranges from about 64°F. in the western extremity of the basin to 67°F. in the southeastern portion of the basin. The maximum recorded temperature of 118 degrees occurred at Hugo, Oklahoma, and at Mount Pleasant, Texas, on 10 August 1936. Smithville, Oklahoma, experienced a record low of -22 degrees on 2 February 1951. Normal monthly temperatures vary from about 83 degrees in August to 42-46 degrees in January. Normal seasonal temperatures range from 82 degrees in summer to 48 degrees in winter. The growing season has a length of about 8 months with the first killing frost occurring about the middle of November and the last killing frost about the middle of March.

The prevailing wind in the area of the basin between Denison Dam and Fulton, Arkansas, is from the south at about 11 miles per hour. For the area downstream from Fulton to Alexandria, La., the prevailing wind is southeast at about 8 miles per hour. The highest recorded wind velocity for these two areas are 77 m.p.h. in July 1936 in the upper portion of the basin and 59 m.p.h. in September 1951 in the lower portion of the basin. The greatest wind movement occurs during the spring months.

7. PHYSIOGRAPHY

The lower Red River Basin includes sections of three physiographic provinces -- Central Lowland, Ouachita province, and the Coastal Plain. Figure 1 shows the physiographic provinces in the area covered by this report.

The Ouachita province and Central Lowland, which comprise the northern third of the basin, are characterized by high ridges of chert and sandstone with intervening wide, flat valleys with their long axes in a general north-south direction. Altitudes range from about 600 feet to about 2,700 feet above sea level. The highest point is located in the Ouachita Mountains along the Arkansas-Oklahoma state line.

The Ouachita province is bounded on the south by the northern margin of the gulfward-dipping rocks of Cretaceous age of the Coastal Plain province. Low relief and the gentle gulfward slope of the land characterize the Coastal Plain province. The streams have wide, nearly flat, flood plains bounded by a series of terraces, which in some places are more than 100 feet higher than the present stream channels. Uplands are irregular and rolling to hilly.

CHAPTER III - GEOLOGY

The geologic formations pertinent to the existence of fresh ground water in the basin range in age from Paleozoic to Recent. The age, occurrence, and water-bearing characteristics of these formations are summarized in table 1. The general geology is shown on the geologic map (Fig. 1).

8. ROCKS OF PALEOZOIC AGE

The formation of Paleozoic age crop out at the northern end of the basin in Arkansas and Oklahoma, and constitute the Ouachita and Arbuckle Mountains. Rocks of Precambrian age crop out in a small area in Johnston County, Oklahoma. The water-bearing properties of the rocks of Precambrian age do not differ from rocks of Paleozoic age. Therefore, the Precambrian is not differentiated in this report. The formations at the surface consist principally of the Arbuckle Limestone, Bigfork Chert, Arkansas Novaculite, Stanley Shale, Jackfork Sandstone, and the Atoka Formation. These formations are extensively and, in places, intricately folded and faulted. The primary porosity of all but the youngest beds has been destroyed by compaction due to deep burial, by deformation pressures, or both. Limited supplies of ground water are available in most places. Ground water occurs principally in secondary openings such as joints, fractures, and separations along bedding planes, and its availability depends upon the extent to which the rocks have been broken or weathered.

The rocks of Paleozoic age extend to the south and are overlain by younger formations of Cretaceous and Tertiary age.

9. CRETACEOUS SYSTEM

The deposits of Cretaceous age are wedge shaped, thinning to a featheredge to the north against the Paleozoic rocks, and thickening rapidly to the south. The Trinity Group, the lowermost group of the Cretaceous System, consists principally of sand, clay, limestone, and conglomerate, and is as much as 5,300 feet thick. This group is a source of moderate quantities[1] of ground water in its outcrop area in Arkansas and Oklahoma, and, in places, downdip in Texas.

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[1] In discussing relative well yields in this report, yields of less than 50 gallons per minute (g.p.m.) are referred to as "small," yields from 50 g.p.m. to 500 g.p.m. as "moderate," and yields over 500 g.p.m. as "large."

The Woodbine Formation lies above the Trinity Group and is separated from it by as much as 900 feet of relatively impermeable strata of the Fredericksburg and Washita Groups. The Woodbine Formation is as much as 600 feet thick and consists chiefly of sand, clay, and lignite. It is a source of moderate supplies of water in parts of the Blue, Muddy Boggy, Kiamichi, and Sulphur River Basins. In northeast Texas, the Eagle Ford Shale, rocks of Austin age and Taylor age, and the Navarro Group overlie the Woodbine and, collectively, are about 3,700 feet thick. Two sands in this sequence, the Blossom Sand in northeast Texas and its equivalent, the Tokio Formation in southwest Arkansas, yield small to moderate quantities of water to wells in their outcrop area. The Nacatoch Sand yields small to moderate quantities of water to wells in its outcrop area in northeast Texas and southwest Arkansas.

10. TERTIARY SYSTEM

The rocks of Tertiary age in the Red River Basin include, in ascending order, the Midway Group, Wilcox Group[2], Carrizo Sand, Cane River Formation, Sparta Sand, Cook Mountain, Cockfield Formation, Jackson and Vicksburg Groups, and sand beds of Miocene age. Of these, the Wilcox Group, Carrizo Sand, Sparta Sand, Cockfield Formation, and the Miocene sands are the most important, or potentially important, aquifers of Tertiary age in the basin, and are capable of yielding moderate to large quantities of water.

The formations of Tertiary age crop out in northeast-trending bands, dip to the southeast and east, and thicken downdip. The oldest rocks are exposed in the northern part of the area, and progressively younger formations crop out in a southerly direction.

The formations of Tertiary age are composed of a heterogeneous sequence of beds of lignitic sands, silts, and clays. Most of the beds are lenticular, and the lenses of sand, silt, and clay pinch out, coalesce, or grade into each other within short distances. Failure to obtain a highly productive well in any location may be attributed to the discontinuity of the sand beds in the area, and, in some cases, to the absence of a productive aquifer.

11. QUATERNARY SYSTEM

The alluvial deposits along the Red River and its tributary streams are in the nature of terraces formed at different stages of

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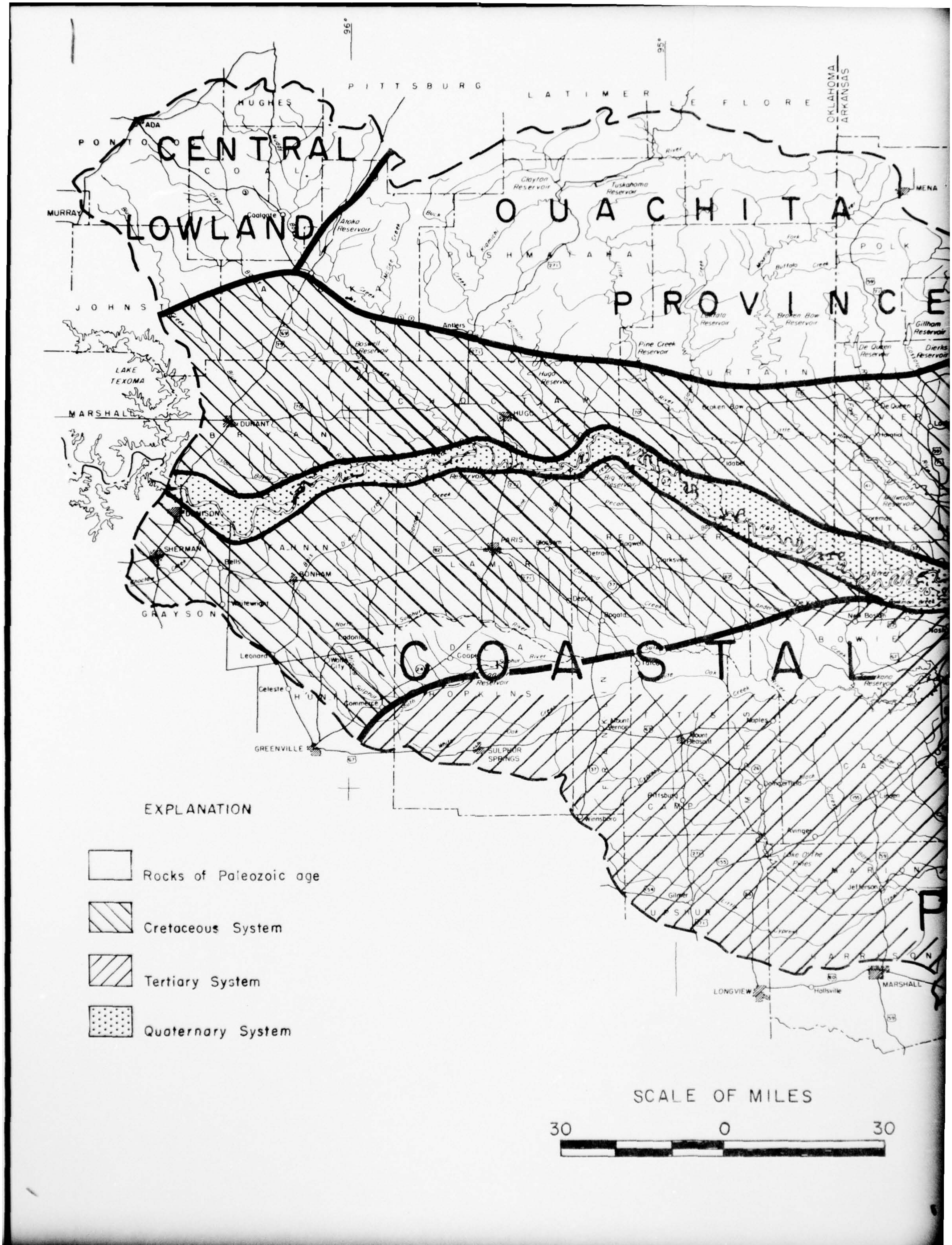
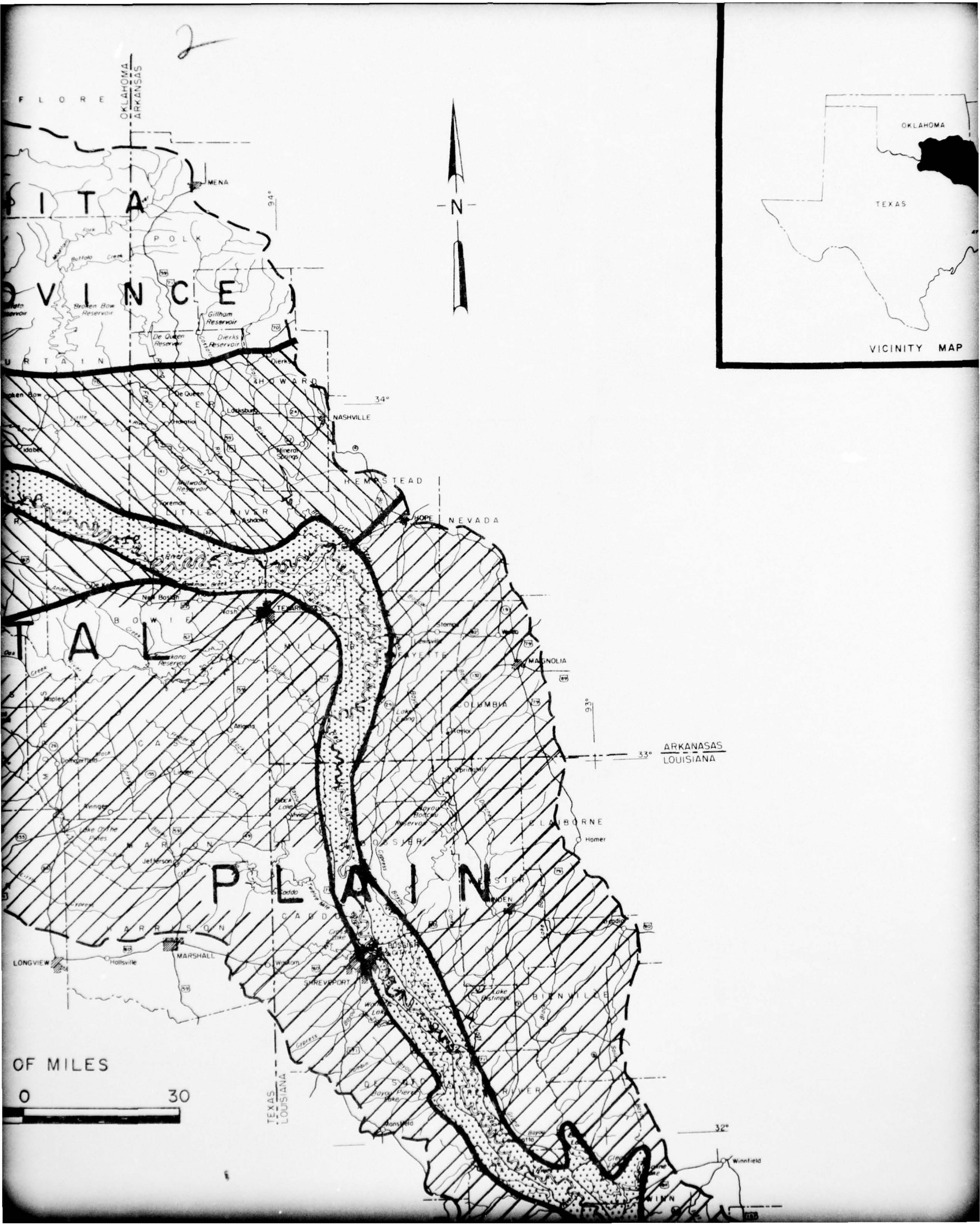
[2] In northeastern Texas, the Wilcox is considered to be a formation; in Arkansas, Louisiana, and elsewhere, it is considered to be a group.

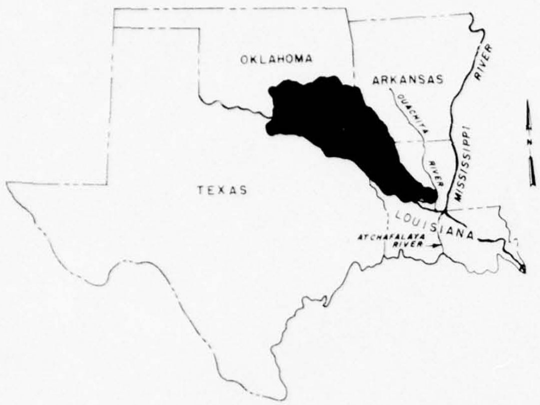


CENTRAL LOWLAND
OUACHITA PROVINCE
COASTAL
P
96°
95°
OKLAHOMA
ARKANSAS
PITTSBURG
LATIMER
LE FLORE
HUGHES
PONTOTOC
COAL
MURRAY
JOHNSTON
MARSHALL
BRYAN
PUSHMATAHA
CHOCTAW
McCURTAIN
POLK
GRAYSON
FANNIN
LAMAR
RED RIVER
BOWIE
DELTA
HOPKINS
HUNT
TITUS
CASS
CAMP
MARION
UPSHUR
HARRISON
LAKE TEXOMA
ADA
Coalgate
Atoka Reservoir
Antlers
Hugo Reservoir
DURANT
HUGO
Broken Bow
Idabel
De Queen
MENA
Clayton Reservoir
Tuskahoma Reservoir
Pine Creek Reservoir
Gillham Reservoir
Dierks Reservoir
DENISON
SHERMAN
Bells
Whitewright
BONHAM
PARIS
Blossom
Detroit
Clarksville
Bogata
Leonard
Celeste
Commerce
GREENVILLE
SULPHUR SPRINGS
Mount Vernon
Mount Pleasant
Naples
Pittsburg
Winnsboro
Daingerfield
Linden
Avinger
Lake O' the Pines
Jefferson
Gilmer
LONGVIEW
Hallsville
MARSHALL
New Boston
EXPLANATION
Rocks of Paleozoic age
Cretaceous System
Tertiary System
Quaternary System
SCALE OF MILES
30
0
30



2
FLORE
OKLAHOMA
ARKANSAS
MENA
ITA
POLK
OVINCE
Broken Bow Reservoir
Gillham Reservoir
De Queen Reservoir
Dierks Reservoir
URTAIN
HOWARD
De Queen
SEVIER
NASHVILLE
34°
94°
Mineral Springs
HEMPSTEAD
Millwood Reservoir
LITTLE RIVER
Ashdown
HOPE
NEVADA
New Boston
BOWIE
TEXARKANA
TAL
Stamps
Lewisville
FAYETTE
MAGNOLIA
COLUMBIA
93°
Atlanta
Naples
CASS
Linden
33°
ARKANASAS
LOUISIANA
Springhill
Avinger
Lake Of The Pines
MARION
Jefferson
CLAIBORNE
Homer
PLAIN
CADDO
HARRISON
MARSHALL
LONGVIEW
Hallsville
SHREVEPORT
BIENVILLE
OF MILES
0
30
TEXAS
LOUISIANA
Mansfield
32°
Winnfield
WINN
N
OKLAHOMA
TEXAS
VICINITY MAP

3



VICINITY MAP

Tertiary System

Quaternary System

4

SCALE OF MILES

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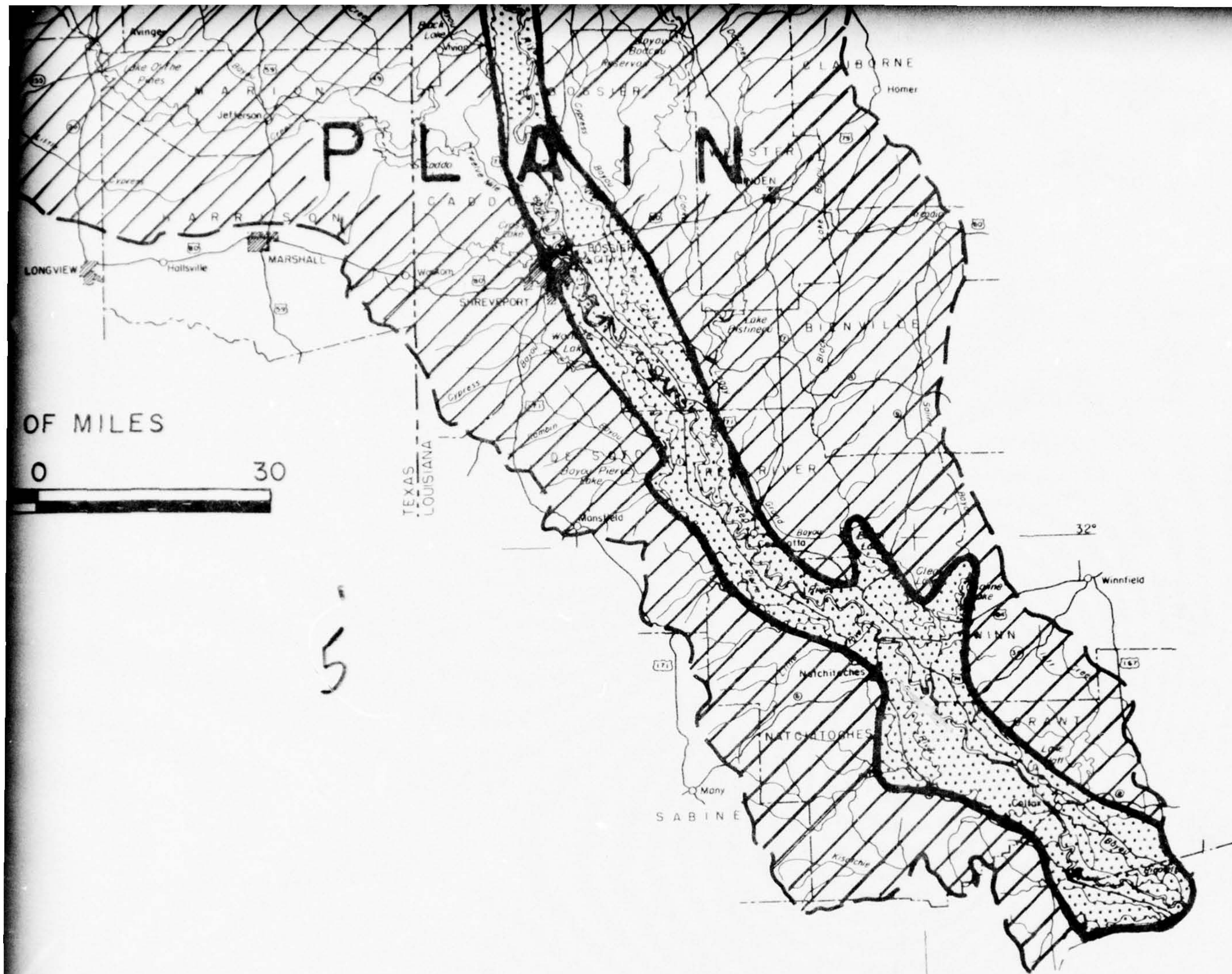

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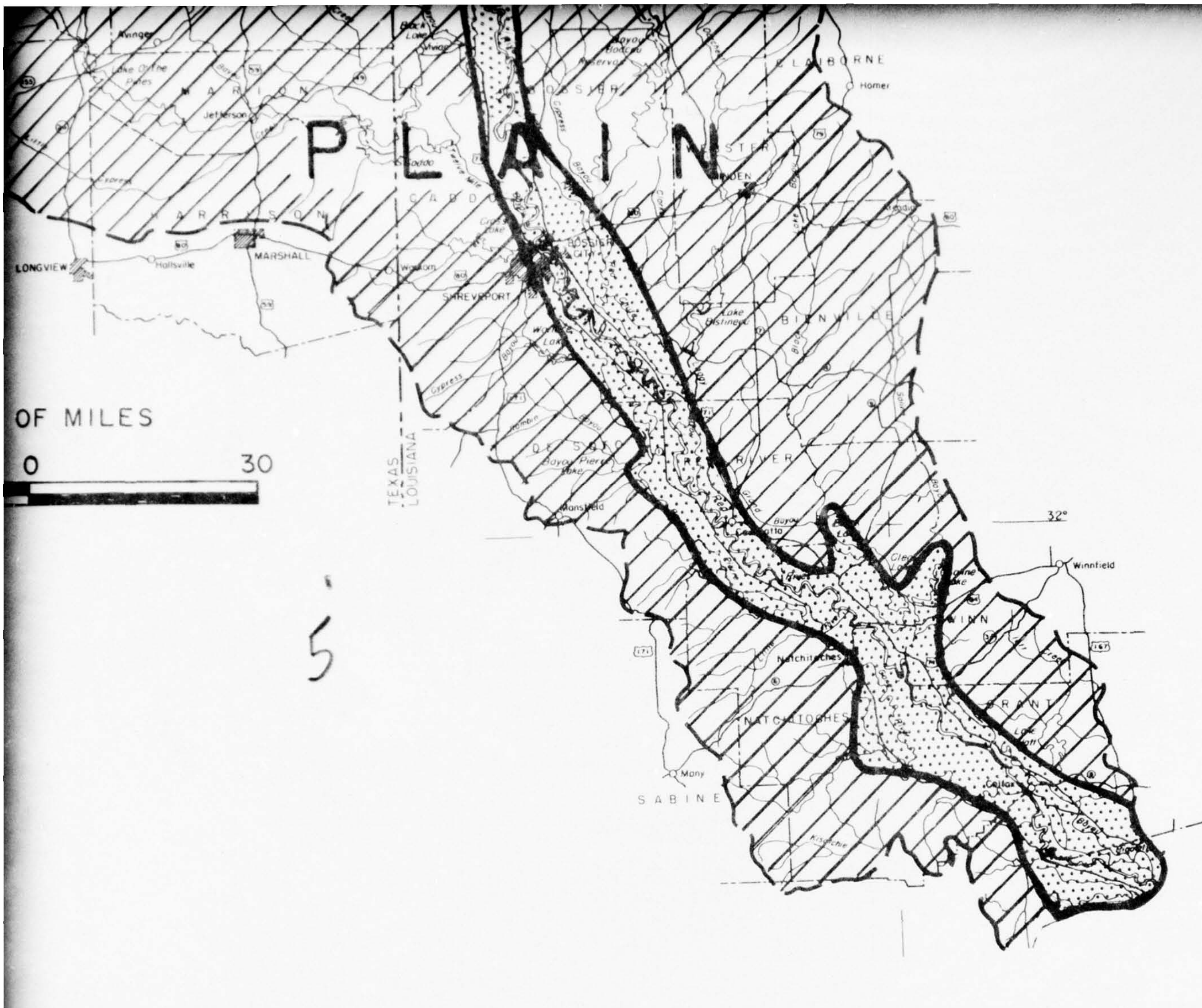

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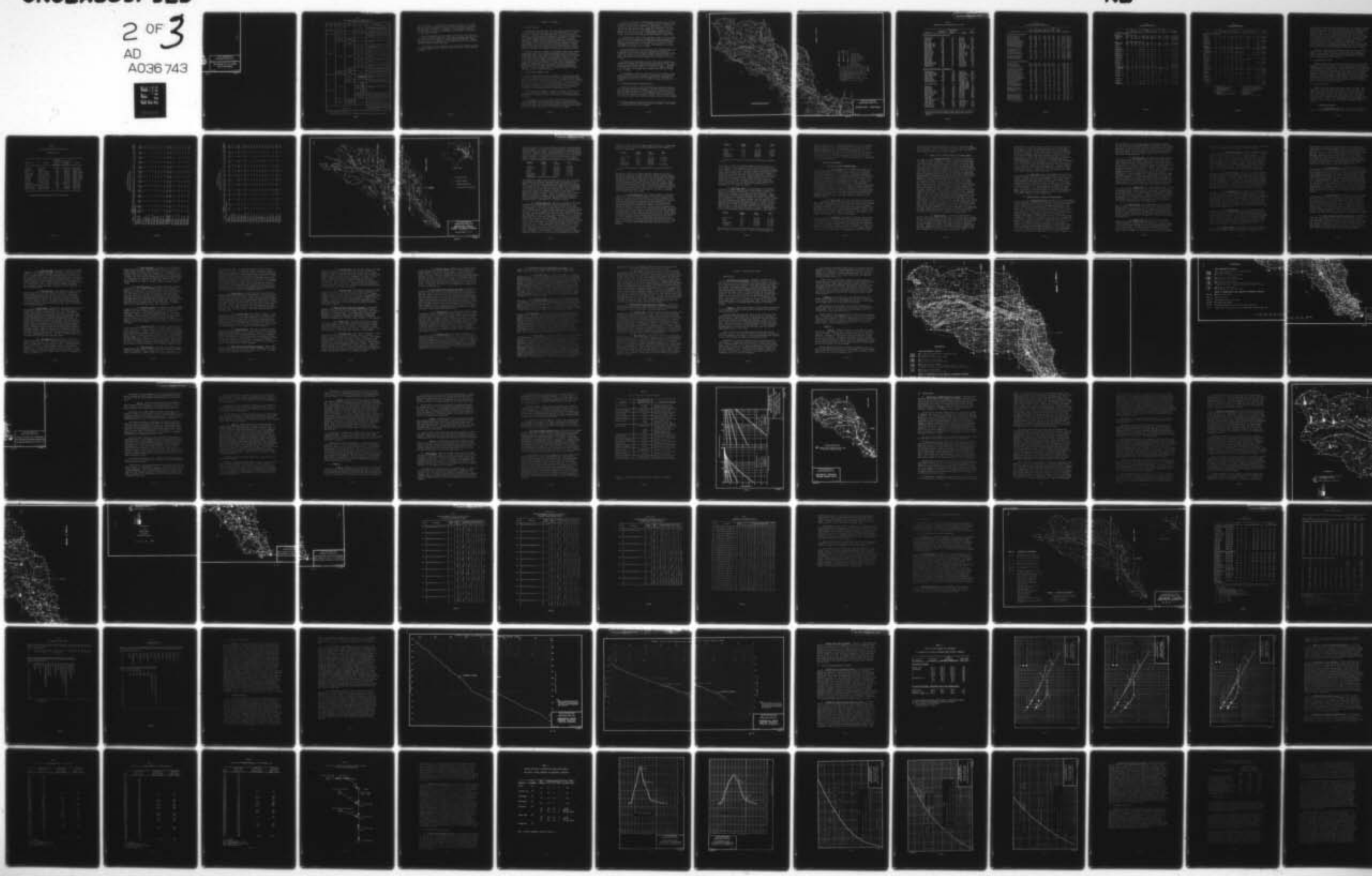

6

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

GENERAL GEOLOGY AND PHYSIOGRAPHIC PROVINCES OF THE LOWER RED RIVER BASIN

JUNE 1968 FILE NO. H-2-24396

FIGURE 1

TABLE 1

GENERALIZED STRATIGRAPHIC COLUMN SHOWING GEOLOGIC UNITS
AND THEIR WATER-SUPPLY CHARACTERISTICS

System	Series	Group	Unit	Water Supply
Quaternary	Recent		Alluvium	Yields moderate to large quantities of hard water chiefly for irrigation.
	Pleistocene		Terrace deposits	Yields moderate quantities of water.
Tertiary	Miocene			Yields moderate to large quantities of soft water.
	Oligocene	Vicksburg		Generally not considered to be water bearing.
	Eocene	Jackson		
		Claiborne	Cockfield	Yields moderate quantities of variable quality water.
			Cook Mountain	Yields small quantities of water to wells.
			Sparta Sand	Yields moderate to large quanities of water.
			Cane River[2]	Yields small to moderate quantities of water.
			Carrizo Sand	Yields small to moderate quantities of water.
		Wilcox[1]		Yields moderate quantities of water.
	Paleocene	Midway		Not known to yield water to wells.
Cretaceous	Gulf	Navarro	Nacatoch Sand	Yields small to moderate quantities of water.
		Taylor		Yields small quantities of water.
			Rocks of Austin Age; Tokio Formation in Ark. and Blossom Sand in Tex.	Yields small to moderate quantities of water.
			Eagle Ford Shale	Yields small quantities of water.
			Woodbine	Yields moderate quantities of water.
	Comanche	Washita and Fredericksburg		Yields small quantities of water.
		Trinity		Yields moderate quantities of water.
Paleozoic rocks				Yields moderate quantities of water in area 3-A. Yields small quantities of water in area 4-A.

1 Eocene and Paleocene in Louisiana.

2 In Texas the equivalents of the Cane River are Reklaw Formation, Queen City Sand, and Weches Greensand.

river development. Consequently, the highest terrace is the oldest, and the lowest (the present flood plain) is the youngest. The older terraces serve as sources of recharge to the flood plain deposits, the lower part of which is contiguous to, and probably a continuation of the terrace material.

The alluvium underlying the present flood plain of the Red River is composed of gravel, sand, silt, and clay, and grades generally from silt and clay at the surface to sand and gravel at the base. Where the upper section is composed of a clay cap, ground water is generally contained under artesian conditions.

The thickness of the alluvium in the flood plain ranges from about 60 feet in Grayson County, Texas, to about 100 feet in the vicinity of Alexandria, La.

12. SOURCE OF DATA

Runoff and streamflow data have been compiled from observations at numerous locations throughout the lower Red River Basin. The location of stations where data have been collected are shown on figure 2. On the main stem of Red River, data collection began with U. S. Weather Bureau gages at Alexandria, Louisiana, in 1872, Shreveport, Louisiana, in 1873, Fulton, Arkansas, in 1885, and Arthur City, Texas, in 1891. Measurements of runoff on the tributary streams in the lower portion of the basin generally began in the 1920's and in the upper portion in the early 1930's. At the present time, there are 7 gaging stations where discharge measurements are available on the main stem and 42 on tributary streams.

The U. S. Geological Survey is the Federal agency with primary responsibility for the collection and tabulation of surface and ground water data. These data are published annually in USGS Water Supply papers which are the principal source of such data. Additional data on river stages and discharges are available in the U. S. Weather Bureau's annual publication "Daily River Stages" and in various publications by the U. S. Army Corps of Engineers on stages and discharges of the Mississippi River and Tributaries. Also, unpublished discharge measurements and gage readings are available in the U. S. Army Corps of Engineers' offices in Tulsa, Oklahoma, and New Orleans, Louisiana.

13. RUNOFF AND STREAMFLOW DATA

Drainage area data on major tributaries of Red River are shown in table 2. These data were extracted from the Arkansas-White-Red Basins Inter-Agency Committee publication "Drainage Area Data, Arkansas, White and Red Rivers" dated November 1954. For the study, drainage area data which have not been published were determined by the procedures outlined in the Subcommittee on Hydrology of the Federal Inter-Agency River Basin Committee Bulletin No. 4, "Inter-Agency Coordination of Drainage Area Data" dated November 1951.

The averages and extremes of monthly and annual runoffs at key locations are shown in table 3. Table 4 shows extremes of stage and discharge, periods of record, and other data for representative locations.

The volume and rate of discharge of the Red River fluctuate over a wide range. Flows on the main stem have been regulated by Denison Dam since 1944 and modified by Texarkana Reservoir on Sulphur River since 1956, Lake O' the Pines Reservoir on Cypress Creek since 1959, and Millwood Reservoir on Little River since 1965.

Prior to construction of Denison Dam, river mile 675 (1957),[1] a maximum flow of 470,000 c.f.s. occurred in 1908 at Colbert, which is about 3 miles below the damsite. A minimum flow of 75 c.f.s. occurred in 1934 at that point. Since the completion of Denison Dam, Colbert has experienced a maximum flow of 102,000 c.f.s. and a minimum flow of 45 c.f.s. The average annual volume of flow at Colbert is 3,780,000 acre-feet. The maximum and minimum annual volumes of flow are 9,740,000 and 250,000 acre-feet, respectively.

At Arthur City, Texas, river mile 582, volume of flow averages 5,918,000 acre-feet annually. The maximum and minimum annual volumes of flow are 15,600,000 and 1,800,000 acre-feet, respectively. Discharge has ranged from a low of 130 c.f.s. in 1956 to a high (estimated) of 400,000 c.f.s. in 1908. The maximum flow recorded since 1944 was 136,000 c.f.s. in 1957.

At Fulton, Arkansas, river mile 405, flow volumes average about 12,740,000 acre-feet annually, with maximums and minimums of 30,280,000 and 4,352,000 acre-feet, respectively. Discharge ranged from a low of 325 c.f.s. in 1956 to a high of 338,000 c.f.s. in 1938. The maximum discharge recorded since 1944 was 270,000 c.f.s. in 1945.

At Shreveport, Louisiana, river mile 277, annual maximum and minimum flow volumes were 39,610,000 and 5,594,000 acre-feet, respectively, with an average volume of 17,630,000 acre-feet. Discharge has ranged from a low of 690 c.f.s. in 1956 to a high of 354,000 c.f.s. in 1908. The maximum flow recorded since 1944 was 303,000 c.f.s. in 1945.

At Alexandria, Louisiana, river mile 103, flow volumes average about 22,210,000 acre-feet annually, with maximums and minimums of 48,960,000 and 7,918,000 acre-feet, respectively. Discharge has ranged from a low of 873 c.f.s. in 1956 to a high of 233,000 c.f.s. in 1945.

14. BASIN DEVELOPMENTS AFFECTING RECORDS

Hydrologic records in the basin have been altered by numerous land and water resource developments. The more significant developments affecting records are the construction of large flood control and multi-purpose reservoirs, the leveed floodway, and navigation and local flood protection projects; removal of the obstructive mass of driftwood on Red River, known as the great Red River raft; pumpage

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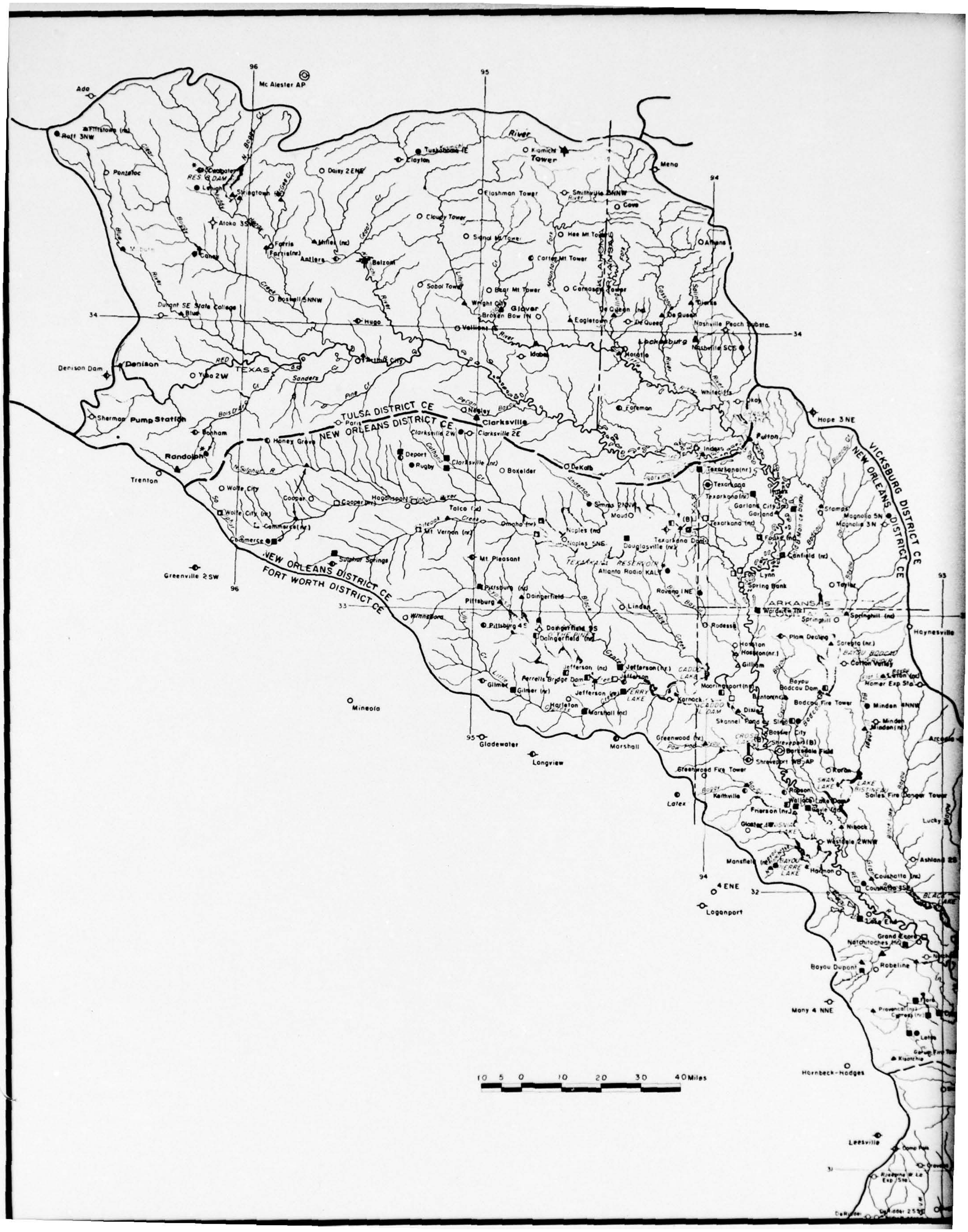
[1] Unless otherwise specified, Red River mileages in this appendix are measured on the 1957 alignment.



TULSA DISTRICT CE
NEW ORLEANS DISTRICT CE
FORT WORTH DISTRICT CE
VICKSBURG DISTRICT CE
TEXAS
ARKANSAS
Mc Alester AP
Ada
Mena
Tower
Clayton
Daisy 2 ENE
Cloudy Tower
Antlers
Belzoni
Atoka 3SW
Lehigh
Stringtown
Pontotoc
Canoy
Boswell 5NNW
Durant SE State College
Hugo
Denison Dam
Denison
Yuba 2W
Sherman
Pump Station
Bonham
Randolph
Trenton
Honey Grove
Paris
Clarksville
Clarksville 2W
Clarksville 2E
Deport
Rugby
Boxelder
DeKalb
Wolfe City
Cooper
Commerce
Sulphur Springs
Mt Vernon (nr)
Talco
Omaho (nr)
Naples
Mt Pleasant
Greenville 2SW
Pittsburg
Daingerfield
Winnsboro
Gilmer
Jefferson
Marshall
Mineola
Gladewater
Longview
Latex
Linden
Atlanta Radio KALT
Douglasville
Texarkana
Texarkana Dam
TEXARKANA RESERVOIR
Maud
Smithville 3NNW
Cove
Athens
Hee Mt Tower
Carter Mt Tower
Sobol Tower
Bear Mt Tower
Glover
Broken Bow
Eagletown
De Queen
Nashville SCS
Lockesburg
Horatio
Idabel
Vallient
Foreman
Fulton
Hope 3NE
Stamps
Magnolia 5N
Magnolia 3N
Garland
Canfield
Taylor
Spring Bank
Lynn
Springhill
Haynesville
Rodessa
Plain Dealing
Sarepta
Cotton Valley
Homer Exp Sta
Minden
Bodcau Dam
Bodcau Fire Tower
Mooringsport
Benton
Shreveport WB AP
Barksdale Field
Greenwood
Greenwood Fire Tower
Keithville
CADDO LAKE
CROSS LAKE
Mansfield
Logansport
Coushatta
Ashland
Lucky
Grand Ecore
Natchitoches
Robeline
Bayou Dupont
Many 4 NNE
Hornbeck-Hodges
Leesville
DeRidder
34
33
32
31
93
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95
96
10 5 0 10 20 30 40 Miles

2

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

HYDROLOGIC STATIONS

JUNE 1968

FILE NO. H-2-24396

TABLE 2

PERTINENT DATA ON MAJOR TRIBUTARIES OF RED RIVER*

Tributary	Drainage area (sq. mi.)	Stream length from mouth (miles)	Stream	River mile
Red River, from Denison Dam to Fulton, Ark.				
Choctaw Creek	261	28	Red River	657.7
Island Bayou	148	31	Red River	631.5
Blue River	676	150	Red River	618.0
Bois d'Arc	416	52	Red River	611.8
Boggy Creek	2,429	25	Red River	591.5
Clear Boggy Creek	1,010	88	Boggy Creek	24.4
Muddy Boggy Creek	1,218	131	Boggy Creek	24.4
North Boggy Creek	231	38	Muddy Boggy Creek	55.6
McGee Creek	175	38	Muddy Boggy Creek	34.6
Sanders Creek	190	33	Red River	584.5
Pine Creek	192	34	Red River	567.0
Kiamichi River	1,830	169	Red River	555.0
Jack Fork Creek	280	24	Kiamichi River	103.5
Tenmile Creek	104	28	Kiamichi River	67.3
Cedar Creek	172	28	Kiamichi River	54.2
Big Pine Creek	166	27	Red River	534.0
Pecan Bayou	175	33	Red River	509.9
Walnut Bayou	134	20	Red River	454.0
Little River	4,260	217	Red River	407.0
Glover Creek	338	56	Little River	127.9
Mountain Fork River	842	95	Little River	87.1
Rolling Fork River	354	50	Little River	72.9
Cossatot River	530	87	Little River	43.5
Saline River	552	85	Little River	22.8
Red River, from Fulton, Ark. to Alexandria, La.				
McKinney Bayou	360	43.6	Red River	339.3
North Sulphur River	449	52.6	Sulphur River	183.0
South Sulphur River	675	71.9	Sulphur River	183.0
Middle Sulphur River	133	25.0	South Sulphur Riv.	28.4
Sulphur River	3,748	183.0	Red River	335.0
Cuthand Creek	403	49.0	Sulphur River	141.3
White Oak Creek	773	90.0	Sulphur River	107.4
Twelvemile Bayou	3,522	142.9	Red River	277.6
Black Cypress Creek	401	48.0	Twelvemile Bayou Cypress Creek	53.6
Little Cypress Creek	696	64.0	Twelvemile Bayou Cypress Creek	51.1
James Bayou	411	34.0	Twelvemile Bayou	29.5
Black Bayou	384	61.0	Twelvemile Bayou	22.4
Wallace Bayou	276	39.2	Bayou Pierre	64.2
Bayou Pierre	1,138	83.9	Red River	185.0
Cane River-Red Bayou	764	68.9	Red River	133.5
Bayou Jean de Jean	92	19.0	Red River	125.8
Bois d'Arc Creek	220	28.8	Red River	391.0
Maniece Bayou	118	25.5	Red River	346.7
Posten Bayou	114	20.0	Red River	320.2
Loggy Bayou	2,649	135.0	Red River	267.5
Bayou Bodcau, Red Chute, and Flat River	1,149	137.2	Loggy Bayou	7.8
Bayou Dorcheat	1,173	100.1	Lake Bistineau	34.9
Saline Bayou	1,405	98.5	Red River	166.1
Black Lake Bayou	960	100.2	Saline Bayou	12.0
Nantachie Creek	81	28.4	Red River	146.8
Bayou Rigolette	418	65.0	Red River	106.0

*These data extracted from "Drainage Area Data, Arkansas, White and Red River Basins" except for Red River main stem mileage which is based on the 1957 alignment.

TABLE 3

RED RIVER BASIN BELOW DENISON DAM
AVERAGE MONTHLY AND ANNUAL RUNOFF AT KEY GAGING STATIONS

Stream and station	Average runoff (c.f.s.)	Monthly runoff Max. (c.f.s.)	Monthly runoff Min. (c.f.s.)	Annual runoff Max. (c.f.s.)	Annual runoff Min. (c.f.s.)	(Average) annual runoff 1,000's Ac-Ft	Average annual runoff (inches)	Period of record
Red River from Denison Dam to Fulton, Ark.								
Red River near Denison, Tex.	2,764	18,840	803	4,527	1,510	2,002	0.94	10/ 1/61 - 9/30/66 (a)
Red River near Colbert, Okla.	5,218	66,960	67	13,450	344	3,780	1.78	1/ 1/06 - 9/30/61
Red River at Arthur City, Tex.	8,173	93,800	242	21,500	2,476	5,918	2.49	1/31/1891 - 9/30/66 (a)
Red River at Index, Ark.	11,840	94,400	586	25,310	4,383	8,574	3.35	8/ 8/17 - 9/30/66 (a)
Blue River near Blue, Okla.	279	3,089	0.4	972	31	202	7.95	6/ 1/36 - 9/30/66 (a)
Bois d'Arc Creek near Randolph, Tex.	45	558	0	59	28	32	8.41	11/17/62 - 9/30/66 (a)
Chickasaw Creek near Stringtown, Okla.	27	385	0	74	4	20	11.36	9/27/55 - 9/30/66 (a)
McGee Creek near Stringtown, Okla.	84	913	0	199	39	61	13.10	4/ 1/56 - 9/30/66 (a)
Muddy Boggy Creek near Farris, Okla.	856	9,630	0	2,758	142	620	10.69	10/ 1/37 - 9/30/66 (a)
Clear Boggy Creek near Caney, Okla.	450	5,684	0	1,568	54	326	8.48	10/ 1/42 - 9/30/66 (a)
Tenmile Creek near Miller, Okla.	69	723	0	179	20	50	13.72	10/ 1/55 - 9/30/66 (a)
Kiamichi River near Belzoni, Okla.	1,681	12,920	0	4,205	514	1,218	16.04	10/ 1/25 - 9/30/66 (a)
Little River near Wright City, Okla.	900	7,041	0	1,984	363	652	18.95	10/ 1/29 - 9/30/31; 10/ 1/44 - 9/30/66 (a)
Little River near Idabel, Okla.	1,632	13,650	1	3,380	737	1,181	19.32	10/ 1/29 - 9/30/46
Little River below Lukfata Creek near Idabel, Okla.	1,586	9,980	0.6	3,485	666	1,148	17.56	6/13/46 - 9/30/66 (a)
Little River near Horatio, Ark.	3,700	29,630	2	7,501	1,533	2,680	18.79	10/ 1/30 - 9/30/66 (a)
Glover Creek near Glover, Okla.	311	1,531	0.3	432	218	225	13.41	10/ 1/61 - 9/30/66 (a)
Pecan Bayou near Clarksville, Tex.	43	524	0	59	28	31	5.81	11/ 1/62 - 9/30/66 (a)
Mountain Fork near Eagletown, Okla.	1,277	10,650	0	2,608	415	925	22.04	3/30/24 - 12/31/25; 10/ 1/29 - 9/30/66 (a)
Rolling Fork near DeQueen, Ark.	272	1,979	0	528	127	197	20.43	10/ 1/48 - 9/30/66 (a)
Cossatot River near DeQueen, Ark.	587	4,270	3	1,087	247	425	22.09	1/19/38 - 9/30/66 (a)
Saline River near Dierks, Ark.	183	1,359	0	309	60	133	20.04	5/13/38 - 9/30/66 (a)
Saline River near Lockesburg, Ark.	196	1,534	0.6	199	194	142	10.24	6/ 9/63 - 9/30/66 (a)
Red River from Fulton, Ark. to Alexandria, La.								
Red River at Fulton, Ark.	17,600	128,000	780	41,830	5,990	12,740	4.56	11/1885 - 12/66 (a)
Red River near Hosston, La.	17,190	93,750	4,745	31,140	11,490	12,450	4.57	10/57 - 9/66 (a)
Red River at Shreveport, La.	24,350	154,800	1,020	54,720	7,710	17,630	5.45	5/1873 - 12/66 (a)
Red River at Alexandria, La.	30,670	198,300	1,600	67,620	10,910	22,210	6.17	1/1872 - 12/66 (a)
McKinney Bayou at Kemps Bridge, Ark.	350	1,900	0	970	130	255	15.47	12/39 - 10/52; 11/56 - 12/66 (a)
North Sulphur River near Cooper, Tex.	219	2,424	0	541	84	158	10.72	6/38 - 9/66 (a)
South Sulphur River near Cooper, Tex.	365	4,357	0	897	67	261	9.30	5/42 - 9/66 (a)
White Oak Creek near Talco, Tex.	379	3,784	0	1,042	69	273	10.36	12/49 - 9/66 (a)
Sulphur River near Talco, Tex.	1,239	11,690	0	2,697	559	896	12.30	10/56 - 9/66 (a)
Sulphur River near Darden, Tex.	2,291	18,630	0	5,740	1,180	1,659	11.21	10/23 - 12/56
Sulphur River at Texarkana Dam, Tex.	2,920	16,810	-	7,110	660	2,128	11.74	7/53 - 12/66 (a)
Sulphur River near Fort Lynn, Ark.	2,700	22,000	0	5,500	700	1,975	9.90	2/48 - 12/66 (a)
Boggy Creek near Daingerfield, Tex.	84	1,195	0	258	10	61	15.81	3/43 - 9/66 (a)
Cypress Creek near Pittsburg, Tex.	355	4,234	0	812	67	257	13.17	3/43 - 1/63
Cypress Creek near Jefferson, Tex.	695	6,980	0	1,640	140	504	11.12	7/24 - 9/59
Cypress Creek below Ferrells Bridge, Tex.	503	3,010	4	969	86	364	8.04	1/60 - 12/66 (a)
Caddo Lake Dam near Mooringsport, La.	-	20,100	0	6,200	0	-	-	5/30 - 12/66 (a)
Kelly Bayou near Hosston, La.	100	723	2	244	32	72	11.59	9/44 - 9/66 (a)
Twelvemile Bayou near Dixie, La.	2,687	23,500	10	5,750	590	1,946	11.63	8/42 - 9/66 (a)
Bayou Bodcau near Sarepta, La.	588	4,460	0	1,140	190	426	14.63	10/38 - 9/66 (a)
Bayou Bodcau Dam, La.	550	3,190	0	1,010	210	401	11.46	11/49 - 12/66 (a)
Cypress Bayou near Benton, La.	100	855	-	214	26	72	10.16	10/55 - 9/66 (a)
Flat Lick Bayou near Leton, La.	66	604	0	160	41	47	13.26	10/56 - 9/66 (a)
Bayou Dorcheat near Springhill, La.	547	4,326	6	1,156	321	388	12.02	10/57 - 9/66 (a)
Bayou Dorcheat near Minden, La.	1,178	9,680	0	2,360	320	853	14.58	7/28 - 9/31; 12/35 - 12/66 (a)
Loggy Bayou near Ninock, La.	2,302	18,600	0	3,940	660	1,667	11.89	8/42 - 12/60
Boggy Bayou near Keithville, La.	79	900	0	239	8	54	12.86	10/38 - 9/66 (a)
Cypress Bayou near Keithville, La.	75	649	0	168	4	54	15.40	11/38 - 9/57
Wallace Lake Dam, La.	240	2,080	0	440	70	174	12.27	12/46 - 12/66 (a)
Bayou Pierre near Lake End, La.	610	10,700	0	1,800	50	447	11.34	5/39 - 12/51; 7/52 - 11/54; 8/56 - 12/66 (a)
Grand Bayou near Coushatta, La.	81	513	0	163	56	58	11.63	10/56 - 9/66 (a)
Black Lake Bayou near Castor, La.	544	3,879	7	1,145	7	394	17.46	5/40 - 9/57
Saline Bayou near Lucky, La.	166	1,122	5	342	42	120	14.63	6/40 - 9/66 (a)
Saline Bayou near Clarence, La.	1,375	8,980	0	2,370	379	996	13.47	10/49 - 12/66 (a)
Nantachie Creek near Montgomery, La.	67	840	0	130	10	49	19.55	8/42 - 12/66 (a)
Cane River near Galbraith, La.	1,820	10,000	0	5,700	300	1,326	36.19	12/28 - 12/66 (a)
Hemphill Creek near Hot Wells, La.	30	240	10	50	20	21	21.89	10/48 - 9/64

(a) Continued in operation

TABLE 4

RED RIVER BASIN BELOW DENISON DAM
PERTINENT DATA FOR KEY STREAM GAGING STATIONS

Location	Zero of gage (ft.m.s.l.)	Miles above mouth of stream	Drainage area (Sq.miles)	Maximum of record: Stage (feet)	Maximum of record: Date	Maximum of record: Discharge (c.f.s.)	Maximum of record: Date	Minimum of record: Stage (feet)	Minimum of record: Date	Minimum of record: Discharge (c.f.s.)	Minimum of record: Date	Period of record (stage and/or discharge)
Red River from Denison Dam to Fulton, Ark.												
RED RIVER	Extremes for period of record:											
Near Denison, Tex.	500.00	674.9	39,720	17.74	6/15/62	43,200	6/15/62	1.91	4/12/64	42	9/12/65	10/ 1/61- 9/30/66(a)
Near Colbert, Okla.	497.36	672.4	39,777	45.5	5/26/08	470,000	5/26/08	4.30	5/ 1, 14/61	12	1/10/44(b)	1/ 1/06- 9/30/61
Arthur City, Tex.	380.07	581.3	44,531	43.2	5/28/08	400,000	5/28/08	1.5	1/15/1892	130	12/11,12/56	1/31/1891- 9/30/66(a)
Index, Ark.	246.87	427.9	48,030	34.25	2/23/38	297,000	2/23/38	2.82	11/ 2,13/63	378	11/ 2,28/56	8/ 8/17- 9/30/66(a)
Fulton, Ark.	224.94	463.0	52,380	37.4	4/ 2/45	338,000	2/24/38	0.1	1896	390	10/26/56	11/ 8/1885- 9/30/05 10/ 1/37- 9/30/42(c) 10/ 1/46-12/31/65(a)
RED RIVER	Extremes subsequent to Denison Dam operation in 1944:											
Near Denison, Tex.	500.00	674.9	39,720	17.74	6/15/62	43,200	6/12-15/62	1.91	4/12/64	42	9/12/65	10/ 1/61- 9/30/66(a)
Near Colbert, Okla.	497.36	672.4	39,777	26.26	6/ 5/57	102,000	6/ 5/57	4.30	5/1,14/61	12	8/21/57	1/ 1/06- 9/30/61
Arthur City, Tex.	380.07	581.3	44,531	28.35	6/ 6/57	136,000	6/ 6/57	4.49	12/11,12/56	130	12/11,12/56	1/31/1891- 9/30/66(a)
Index, Ark.	246.78	427.9	48,030	28.56	6/ 8/57	154,000	6/ 8/57	3.15	11/28/56	378	11/2,28/56	8/ 8/17- 9/30/66(a)
BLUE RIVER Near Blue, Okla.	503.36	38.8	476	31.81(d)	2/17/38	34,400	2/17/38	(e)	(f)	0	(f)	6/ 1/36- 9/30/66(a)
BOIS D'ARC CREEK Near Randolph, Tex.	564.38	(g)	72	15.69(h)	9/22/65	7,820	9/22/65	(e)	(f)	0	(f)	11/17/62- 9/30/66(a)
CHICKASAW CREEK Near Stringtown, Okla.	540.26	5.0	33	21.54	10/14/62	18,800	10/14/62	(e)	(f)	0	(f)	9/27/55- 9/30/66(a)
McGEE CREEK Near Stringtown, Okla.	623.18	[illegible].7	87	16.79	4/26/57	10,200	4/26/57	(e)	(f)	0	(f)	4/ 1/56- 9/30/66(a)
MUDDY BOGGY CREEK Near Farris, Okla.	444.54	57.7	1,087	46.94	6/17/45	61,900	6/17/45	(e)	(f)	0	(f)	10/ 1/37- 9/30/66(a)
CLEAR BOGGY CREEK Near Caney, Okla.	485.05	24.1	720	26.9	2/ /38	52,800	12/11/46	(e)	(f)	0	(f)	10/ 1/42- 9/30/66(a)
TENMILE CREEK Near Miller, Okla.	475.89	11.6	68	20.69	5/ 2/58	5,930	5/ 2/58	(e)	(f)	0	(f)	10/ 1/55- 9/30/66(a)
KIAMICHI RIVER Near Belzoni, Okla.	389.91	47.7	1,423	44.2	10/ /15	71,400	2/18/38	(e)	(f)	0	(f)	10/ 1/25- 9/30/66(a)
LITTLE RIVER Near Wright City, Okla.	346.76	140.6	645	45.77	9/16/50	78,200	5/ 6/61	(e)	(f)	0	(f)	10/ 1/29- 9/30/31 10/ 1/44- 9/30/66(a)
Near Idabel, Okla.	318.52	111.4	1,146	39.3	2/18/38	86,000	2/18/38	(e)	(f)	0	(f)	10/ 1/29- 9/30/46
Below Lukfata Creek, near Idabel, Okla.	312.08	103.4	1,226	39.7	2/ /38	86,000	2/ /38	4.32	9/15,16/56	0.4	(f)	6/13/46- 9/30/66(a)
Near Horatio, Ark.	272.89	72.0	2,674	38.0	8/ /15	124,000	8/ /15	3.09	8/25-27/34	1.0	8/18, 9/1/34	10/ 1/30- 9/30/66(a)
GLOVER CREEK Near Glover, Okla.	378.70	9.2	315	20.95(i)	2/ 9/65	(g)	2/ 9/65	1.94	11/ 7-10/63	0	(f)	10/ 1/61- 9/30/66(a)
PECAN BAYOU Near Clarksville, Tex.	365.00	(g)	100	8.32(j)	2/10/65	6,450	2/10/65	(e)	(f)	0	(f)	11/ 1/62- 9/30/66(a)
MOUNTAIN FORK Near Eagletown, Okla.	333.87	8.9	787	26.73	5/20/60	101,000	5/20/60	(e)	(f)	0	(f)	3/30/24-12/31/25 10/ 1/29- 9/30/66(a)
ROLLING FORK Near DeQueen, Ark.	318.24	17.0	181	25.6	8/27/47	110,000	8/27/47	(e)	(f)	0	(f)	10/ 1/48- 9/30/66(a)
COSSATOT RIVER Near DeQueen, Ark.	335.48	33.5	361	20.70	5/ 6/61	62,000	5/ 6/61	1.70	8/30-9/1/43	1.2	8/30, 9/1/43	1/19/38- 9/30/66(a)
SALINE RIVER Near Dierks, Ark.	353.09	50.7	124	22.50	5/ 6/61	52,000	5/ 6/61	(e)	(f)	0	(f)	5/13/38- 9/30/66(a)
Near Lockesburg, Ark.	300.00	30.0	260	16.93(k)	4/23/64	10,000	4/23/64	2.10	10/ 8/63	0.2	11/6/63	6/ 9/63- 9/30/66(a)

TABLE 4 (cont'd)

RED RIVER BASIN BELOW DENISON DAM
PERTINENT DATA FOR KEY STREAM GAGING STATIONS

Location	Zero of gage (ft.m.s.l.)	Miles above mouth of stream	Drainage area (Sq.miles)	Maximum of record: Stage (feet)	Maximum of record: Date	Maximum of record: Discharge (c.f.s.)	Maximum of record: Date	Minimum of record: Stage (feet)	Minimum of record: Date	Minimum of record: Discharge (c.f.s.)	Minimum of record: Date	Period of record (stage and/or discharge)
Red River from Fulton, Ark. to Alexandria, La.												
RED RIVER												
Fulton, Ark.	224.9	405.0	52,380	37.4	4/ 2/45	338,000	2/24/38	0.1	9/20, 25/96	325	10/26/56	11/1885-12/66(a)
Shreveport, La.	131.5	277.0	60,613	38.3	4/ 7/45	354,000	6/15/08	0.2	11/ 8, 9/39	690	10/30/56	5/1873-12/66(a)
Alexandria, La.	44.3	104.0	67,500	45.2	4/16,18/45	233,000	4/17/45	-3.7	9/29/81	873	10/30/56	1/1872-12/66(a)
McKINNEY BAYOU												
Kemps Bridge, Ark.	199.6	11.0	309	21.3	4/27/66	7,090	4/30/66	4.4	8/ 9/64(l)	0	11/29/66(l)	12/39-10/52; 11/56-12/66(a)
NORTH SULPHUR RIVER												
Near Cooper, Tex.	377.4	15.6	276	27.0	2/ 9/65	48,000	2/ 9/65	1.0	10/26/64	0	9/20/65(l)	6/38- 9/65(a)
SOUTH SULPHUR RIVER												
Near Cooper, Tex.	374.9	16.1	527	23.1	4/29/53	25,000	2/10/65	-0.4	11/13/63	0	9/20/65(l)	5/42- 9/65(a)
SULPHUR RIVER												
Near Talco, Tex.	209.8	162.5	1,365	25.7	5/ 3/58	50,600	5/ 3/58	1.0 est	10/30/63(l)	0	10/30/63(l)	10/56- 9/65(a)
Near Darden, Tex.	220.6	104.7	2,774	37.6	4/ 1/45	157,000	4/ 1/45	0.4	7/ 1/18	0	10/ 1/64(l)	10/23-12/56
Texarkana Dam, Tex.	0.0	44.5	3,400	252.6	5/ 9/66	170,000(m)	6/12/57	220.0(n)	-	2,580(m)	9/21-30/54	7/53-12/66(a)
Fort Lynn, Ark.	174.5	6.2	3,739	34.7	2/21/50	37,688	11/18/46	3.0	1/31/64	0	12/24/62(l)	2/48-12/66(a)
CYPRESS CREEK												
Near Pittsburg, Tex.	247.5	110.0	366	28.3	4/27/38	58,500	3/30/45	-	-	0	11/ 4/56(l)	3/43- 1/63
Near Jefferson, Tex.	183.7	72.2	850	28.8	4/ 1/45	57,100	4/ 1/45	-	-	0	(o)	7/24- 9/59
Ferrells Br. Dam, Tex.	0.0	72.2	850	245.4	5/ 5/66	515,830(m)	5/ 7/58	228.5(n)	-	60(m)	8/22/57	10/57-12/66(a)
CADDO LAKE												
Caddo Lake Dam, La.	0.0	23.8	2,744	182.6	5/ 5/58	783,268(m)	5/ 5/58	166.0	11/ 2/34	117,720(m)	11/16,17/63	1/21-12/66(a)
TWELVEMILE BAYOU												
Near Dixie, La.	140.0	17.3	3,137	39.5	4/ 5/45 5/ 5/58	38,400	5/ 5/58	2.0	11/ 6/63(l)	0.2	11/ 6/63(l)	8/42-9/65(a)
BAYOU BODCAU												
Bayou Bodcau Dam, La.	0.8	62.3	683	196.7	5/11/58	301,036	5/11/58	157.0(p)	7/25/60(l)			11/49-12/66(a)
BAYOU DORCHEAT												
Near Minden, La.	133.8	45.0	1,097	24.9	5/ 1/58	44,800	5/ 1/58	0.8	9/30/31	0	8/15/64(l)	7/28- 9/31 12/35-12/65(a)
LOGGY BAYOU												
Near Ninock, La.	100.3	7.5	2,628	50.2	4/ 8/45	32,600	5/ 4/58	9.4	10/24/56	0	11/ 7/51(l)	8/42-12/60
CYPRESS BAYOU												
Near Keithville, La.	162.1	8.0	66	13.6	8/ 3/55	23,700	8/ 3/55	-	-	0	(o)	11/38- 9/57
BAYOU PIERRE												
Wallace Lake Dam, La.	0.0	67.4	266	153.0	5/18/53	56,372(m)	5/18/53	139.2	11/11/48(l)	2,780(m)	10/28/48(l)	12/46-12/65(a)
Near Lake End, La.	83.1	23.4	739	47.2	4/13/45	11,900	9/25/58	8.4	7/30/65(l)	0	5/ 4/57(l)	5/39-12/51; 7/52-11/54; 8/56-12/66(a)
SALINE BAYOU												
Near Lucky, La.	152.6	60.7	154	12.9	1/ 1/45	13,500	1/ 1/45	1.7	8/28/64	2.4	8/14/54	6/40- 9/65(a)
Near Clarence, La.	72.8	6.7	1,386	43.6	4/45	14,200	5/19/53	1.2	11/ 1/64(p)	1.4	11/18/64(l)	10/49-12/65(a)
CANE RIVER												
Near Gailbraith, La.	54.3	11.0	687	49.9	4/16-18/45	10,331	6/ 7/50	9.3	1/20/53	0	11/18/64(l)	12/38-12/66(a)
HEMPHILL CREEK												
Near Hotwells, La.	87.8	-	18	15.5	4/29/53	8,320	4/29/53	1.3	9/15,16/64	5.3	8/19/63(l)	10/48- 9/64
NANTACHIE CREEK												
Near Montgomery, La.	107.4	11.1	47	14.6	5/17/53	10,500	5/17/53	0.8	10/23/65	0	9/21/65(l)	8/42-12/65(a)
BAYOU RIGOLETTE												
Near Pineville, La.	0.0	4.7	402	88.3 HWM	5/53	3,530	2/15/66	57.9	10/24,25/53	0	5/13/66(l)	Intermittent 1946-47 2/48-12/66(a)

(a) Continued in operation.
(b) Occurred during closure of Denison Dam.
(c) Monthly records available October 1931-March 1932, January 1938-December 1942, May 1943 and August 1945 to date.
(d) At site and datum then in use.
(e) Pool at gage or streambed dry; stage not pertinent.
(f) Several times.
(g) Undetermined.
(h) Maximum stage since at least 1922, 24.6 feet about 1935, from information by State Highway Department and local resident.
(i) Flood in May 1961 reached a stage of 28.84 feet, from flood mark. Flood in 1908 was higher than that in May 1961, from information by local residents.
(j) Maximum stage since at least 1910, about 12 feet in 1957, from information by local residents.
(k) Flood of May 6 or 7, 1961, reached a stage of about 25.7 feet, from flood marks.
(l) Also on earlier dates.
(m) Reservoir contents in acre-feet.
(n) Minimum pool elevation.
(o) Several times.
(p) Gage readings not observed below this elevation.

of surface and ground water for irrigation and water supply; extensive construction, by the Soil Conservation Service, of watershed protection works utilizing small reservoirs and conservation programs; and changes in land use. The large flood control and multi-purpose reservoirs have exerted the most significant influence on records. These reservoirs, existing and under construction, as shown in table 5, have some regulatory effect on flows from over one-third of the drainage area in the basin. Exclusive of the storage in Denison Dam, they have a combined flood control storage capacity of 7,262,300 acre-feet. Denison Dam controls flow into the basin from 33,783 square miles of contributing drainage area in the upper Red River Basin and has 2,660,000 acre-feet of flood control storage.

Future developments will continue to exert an impact on hydrologic records. The construction of large reservoirs, changes in land use, and projects for watershed protection and development will all affect future records, with the most significant overall effect coming from the large reservoirs.

15. DISTRIBUTION OF FLOW

Average monthly flows and periods of record for 45 locations in the basin are shown in table 6. Above average flow takes place predominantly in the 5-month period January through May with the greatest runoff normally occurring in May. About 76 percent of the annual runoff occurs during this same period. Below normal flow is associated with the 4-month period July through October with the least runoff normally occurring in August. During this low flow period, about 12 percent of the annual runoff occurs. Figure 3 shows the geographical distribution of average annual runoff based on flow data shown in table 3. The lines of equal runoff are general for the study area and obscure local variations in runoff.

16. FLOODS OF RECORD

Historical records of rainfall and streamflow indicate that, subsequent to 1900, flooding on Red River occurred in 1902, 1903, 1905, 1908, 1915, 1920, 1927, 1930, 1938, 1945, 1953, 1957, and 1958. Recent flooding on one or more major tributary streams in the basin occurred in 1944, 1945, 1946, 1953, 1957, 1958, 1960, 1961, and 1966. Maximum stages and discharges for key gaging locations are shown in table 4. A description of selected floods which occurred on Red River and some of the major tributary streams follows.

a. <u>Floods on Red River.</u>

(1) <u>February-March 1938.</u> The storm of 14-22 February occurred at a time when the river and most of the tributaries above

TABLE 5

RED RIVER BASIN BELOW DENISON DAM

RESERVOIR DATA

Reservoir	Stream	Total Drainage Area (Sq Mi)	Flood Control Storage (Ac-Ft)	Status
Denison	Red River	39,719*	2,660,000	Existing
Pat Mayse	Sanders	175	64,500	Existing
Hugo	Kiamichi River	1,709	809,500	Under Const
Pine Creek	Little River	635	388,100	Under Const
Broken Bow	Mt. Fork River	756	450,000	Under Const
DeQueen	Rolling Fork	169	101,200	Under Const
Gillham	Cossatot River	271	188,700	Under Const
Dierks	Saline River	113	67,100	Under Const
Millwood	Little River	4,144	1,651,400	Existing
Texarkana	Sulphur River	3,400	2,509,000	Existing
Ferrells Bridge	Cypress Creek	850	587,200	Existing
Wallace Lake	Cypress Bayou	260	88,300	Existing
Bayou Bodcau	Bayou Bodcau	656	357,300	Existing

*Contributing Drainage Area 33,783 Square Miles

TABLE 6

RED RIVER BASIN BELOW DENISON DAM

AVERAGE MONTHLY FLOW IN CUBIC FEET PER SECOND

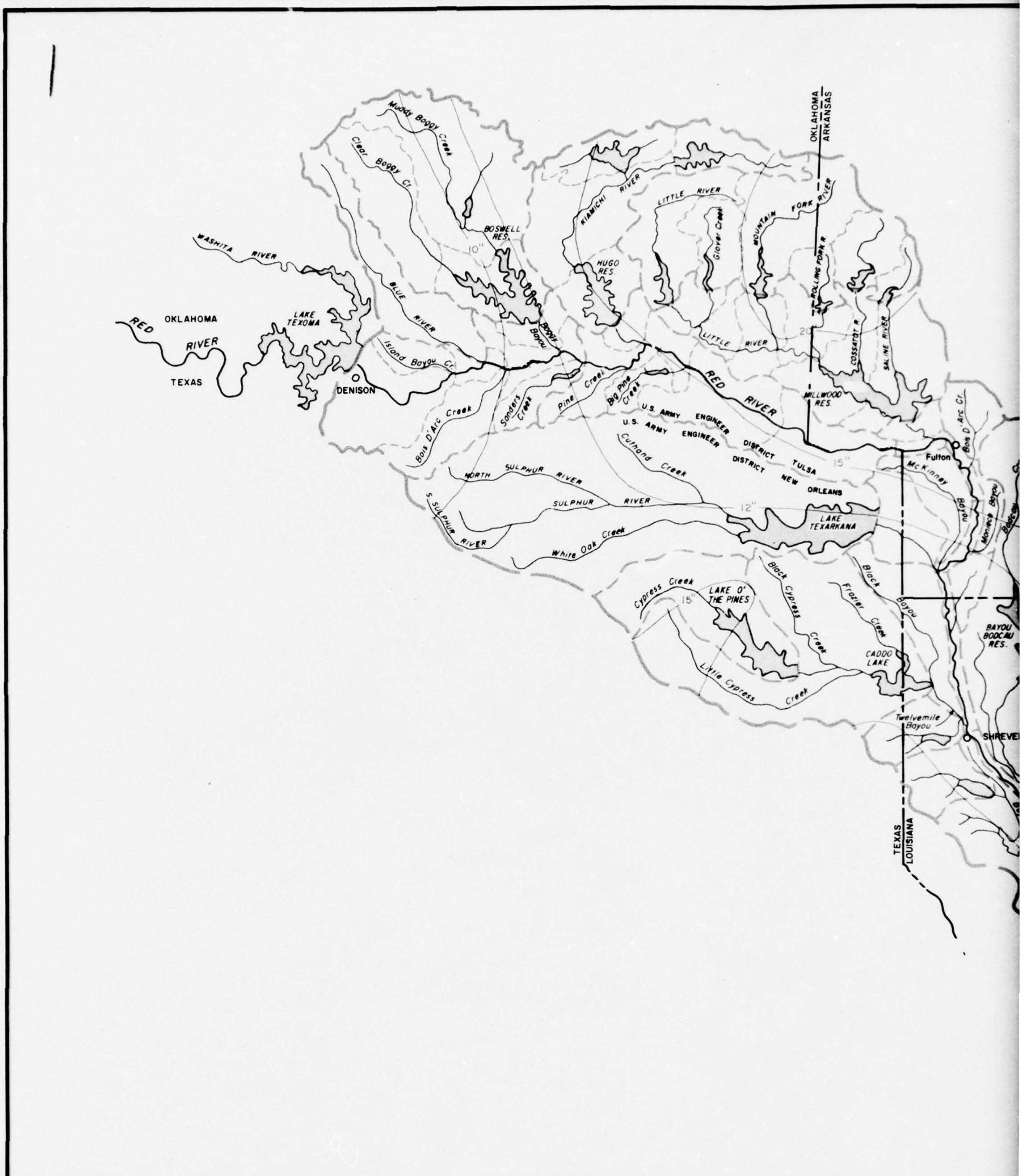
Location	Drainage area (Sq.Mi.)	October	November	December	January	February	March	April	May	June	July	August	September	Period of record
Red River from Denison Dam to Fulton, Ark.														
RED RIVER														
Near Denison, Tex.	39,720	2,680	2,540	2,840	2,730	1,670	1,340	2,260	2,540	5,940	3,300	2,770	2,520	1961-66
Near Colbert, Okla.	39,777	6,940	3,350	3,090	2,670	3,330	2,980	5,940	11,380	10,910	4,940	3,300	3,730	1924-61
Arthur City, Tex.	44,531	7,400	5,610	4,870	4,940	7,910	6,360	12,200	16,410	16,050	6,830	4,330	4,550	1936-66
Index, Ark.	48,030	8,810	7,910	7,640	9,320	13,950	11,950	19,080	24,620	19,260	8,990	5,090	5,590	1936-66
BLUE RIVER														
Near Blue, Okla.	476	154	212	179	179	380	328	558	566	391	169	98	142	1936-66
BOIS D'ARC CREEK														
Near Randolph, Tex.	72	3	53	13	10	61	13	172	46	20	1	0	67	1962-66
CHICKASAW CREEK														
Near Stingtown, Okla.	33	23	29	15	11	26	35	77	62	16	17	1	17	1955-66
McGEE CREEK														
Near Stingtown, Okla.	87	48	83	58	40	89	112	187	175	38	66	15	51	1956-66
MUDDY BOGGY CREEK														
Near Farris, Okla.	1,087	373	499	520	427	1,260	1,050	1,950	1,980	1,050	531	252	442	1937-66
CLEAR BOGGY CREEK														
Near Caney, Okla,	720	215	267	307	217	493	634	859	1,140	635	240	116	279	1942-66
TENMILE CREEK														
Near Miller, Okla.	68	53	73	62	37	90	76	163	116	45	45	7	39	1955-66
KIAMICHI RIVER														
Near Belzoni, Okla.	1,423	556	1,020	1,520	2,100	2,700	2,270	3,510	3,360	1,530	735	252	725	1926-66
LITTLE RIVER														
Near Wright City, Okla.	645	328	628	748	1,170	1,550	1,400	1,610	1,830	582	471	177	450	1944-66
Near Idabel, Okla.	1,146	324	935	1,740	2,490	2,780	2,840	2,990	3,260	1,490	386	204	214	1929-46
Below Lukfata Creek near Idabel, Okla.	1,226	595	1,110	1,420	2,150	2,580	2,150	2,870	3,470	785	911	476	732	1946-66
Near Horatio, Ark.	2,674	1,110	2,260	3,520	5,590	6,320	6,040	6,890	7,210	2,450	1,390	756	1,020	1930-66
GLOVER CREEK														
Near Glover, Okla.	315	137	340	291	382	588	483	777	408	64	16	107	174	1962-66
PECAN BAYOU														
Near Clarksville, Tex.	100	9	15	5	66	122	65	218	60	10	6	0	9	1962-66
MOUNTAIN FORK														
Near Eagletown, Okla.	787	458	888	1,390	2,060	2,280	2,150	2,170	2,340	776	493	280	350	1929-66
ROLLING FORK														
Near DeQueen, Ark.	181	95	178	248	404	477	448	585	488	107	93	54	102	1948-66
COSSATAT RIVER														
Near DeQueen, Ark.	361	183	404	595	753	1,130	1,060	1,160	977	276	202	139	223	1938-66
SALINE RIVER														
Near Dierks, Ark.	124	54	118	192	235	343	343	375	326	81	63	22	54	1938-66
Near Lockesburg, Ark.	260	6	15	24	147	398	321	885	346	97	9	80	22	1963-66

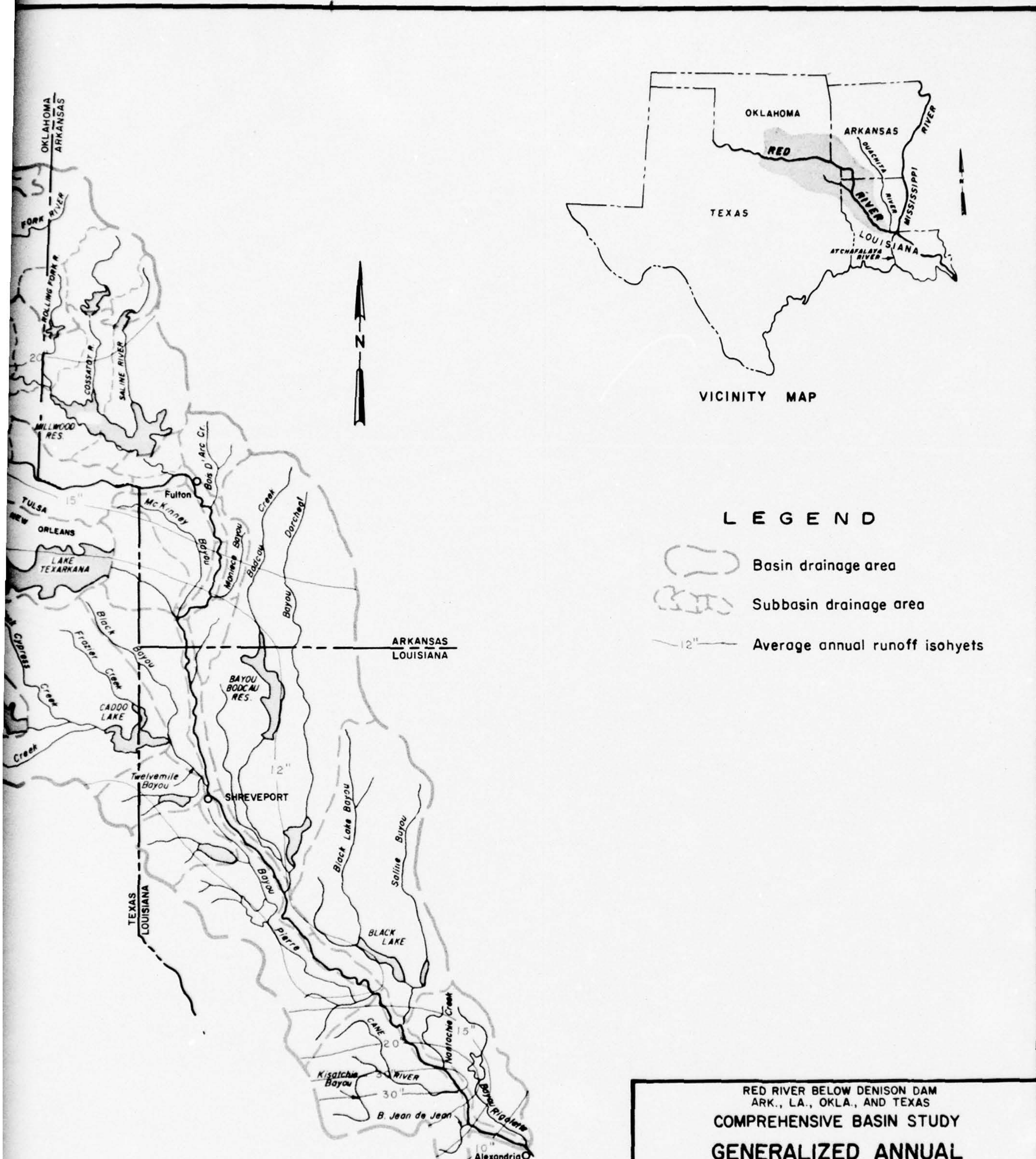
TABLE 6 (cont'd)

RED RIVER BASIN BELOW DENISON DAM

AVERAGE MONTHLY FLOW IN CUBIC FEET PER SECOND

Location	Drainage area (Sq.Mi.)	October	November	December	January	February	March	April	May	June	July	August	September	Period of record
Red River from Fulton, Ark. to Alexandria, La.														
RED RIVER														
Fulton, Ark.	52,380	9,420	10,145	13,805	18,865	23,040	22,170	27,500	37,630	24,860	11,370	5,845	6,920	1928-65
Alexandria, La.	67,500	12,194	15,547	24,249	38,680	47,046	45,940	47,656	56,408	40,756	19,596	10,773	9,185	1929-65
NORTH SULPHUR RIVER Near Cooper, Tex.	276	104	195	185	197	295	190	442	468	312	90	20	133	1950-65
SOUTH SULPHUR RIVER Near Cooper, Tex.	527	168	337	315	375	595	445	595	825	395	115	50	170	1943-65
SULPHUR RIVER														
Near Talco, Tex.	1,365	540	1,465	1,500	1,128	1,188	1,090	2,170	2,970	1,410	600	80	730	1957-65
Near Darden, Tex.	2,774	640	960	2,265	3,525	3,620	3,665	4,180	5,130	2,130	810	190	375	1924-56
WHITE OAK CREEK Near Talco, Tex.	494	129	368	468	434	515	373	914	835	240	129	18	120	1951-65
CYPRESS CREEK														
Near Pittsburg, Tex.	366	147	233	332	520	596	635	604	750	249	87	18	87	1944-62
Near Jefferson, Tex.	850	151	291	641	1,096	1,082	1,132	1,260	1,560	631	252	118	123	1925-59
BOGGY CREEK Near Daingerfield, Tex.	72	34	57	71	107	153	155	166	177	44	12	2	24	1944-65
BLACK BAYOU Near Gilliam, La.	364	63	267	252	569	725	649	779	819	290	83	34	73	1943-59
KELLY BAYOU Near Hosston, La.	116	17	75	102	172	182	182	179	176	59	25	11	16	1945-65
TWELVEMILE BAYOU Near Dixie, La.	3,137	560	1,296	2,325	4,247	4,576	4,925	4,414	5,731	2,565	804	283	520	1943-65
BAYOU BODCAU Near Serapta, La.	546	75	302	580	988	1,252	1,012	1,153	1,139	256	216	37	51	1939-65
BAYOU DORCHEAT Near Minden, La.	1,097	130	445	957	2,003	2,431	2,304	2,359	2,456	490	349	108	103	1938-65
LOGGY BAYOU Near Ninock, La.	2,628	510	820	1,080	2,460	4,910	4,325	3,765	5,905	2,288	888	390	285	1949-60
BOGGY BAYOU Near Keithville, La.	79	28	46	96	152	157	178	114	118	35	8	13	6	1939-65
CYPRESS BAYOU Near Keithville, La.	66	33	43	71	139	154	125	114	143	36	13	31	1	1940-57
BLACK LAKE BAYOU Near Castor, La.	423	130	261	421	1,057	1,098	998	874	1,019	353	182	91	68	1941-57
SALINE BAYOU														
Near Lucky, La.	154	43	118	173	294	311	282	244	271	122	57	34	38	1941-65
Near Clarence, La.	1,382	339	476	1,143	1,547	2,125	2,430	3,387	2,032	1,647	699	382	296	1950-65
NANTACHIE CREEK Near Montgomery, La.	47	4	28	32	107	115	138	154	155	31	15	6	14	1943-65


OKLAHOMA
ARKANSAS
Muddy Boggy Creek
Clear Boggy Cr.
BOSWELL RES.
10"
WASHITA RIVER
BLUE RIVER
KIAMICHI RIVER
LITTLE RIVER
Glover Creek
MOUNTAIN FORK RIVER
ROLLING FORK R.
HUGO RES.
COSSATOT R.
SALINE RIVER
OKLAHOMA
RED RIVER
TEXAS
LAKE TEXOMA
DENISON
Boggy Bayou
Island Bayou Cr.
LITTLE RIVER
20"
MILLWOOD RES.
Bois D'Arc Creek
Sanders Creek
Pine Creek
Big Pine Creek
RED RIVER
U.S. ARMY ENGINEER DISTRICT TULSA
U.S. ARMY ENGINEER DISTRICT NEW ORLEANS
Cuthand Creek
15"
Fulton
Bois D'Arc Cr.
McKinney Bayou
Monkey Bayou
NORTH SULPHUR RIVER
SULPHUR RIVER
12"
S. SULPHUR RIVER
LAKE TEXARKANA
White Oak Creek
Black Cypress Creek
Black Bayou
Frazier Creek
Cypress Creek
15"
LAKE O' THE PINES
BAYOU BODCAU RES.
CADDO LAKE
Little Cypress Creek
Twelvemile Bayou
TEXAS
LOUISIANA



RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

GENERALIZED ANNUAL RUNOFF VOLUMES IN INCHES

SCALE OF MILES
25 0 25

JUNE 1968 FILE NO H-2-24396

FIGURE 3

Fulton were above flood stage resulting from heavy rains during the preceding month. The main center of the storm was located north of the Red River Basin, adjacent to the Boggy Creek and Kiamichi River Watersheds. Maximum rainfall exceeded 10 inches in the northwestern portion of the basin, while smaller quantities fell over the remainder of the basin. Tributaries in the north established record maximum stages and discharges during the flood. Peak stages and flows at the major gaging stations along the river are shown below:

Station	Stage (feet)	Flow (c.f.s.)	Date
Colbert	27.3*	138,000	2/18/38
Arthur City	34.3	222,000	2/19/38
Index	34.3	297,000	2/23/38
Fulton	36.4	338,000	2/24/38
Shreveport	33.5	211,000	3/ 1/38
Alexandria	39.8	143,000	3/ 7/38

*Adjusted to present site and datum.

The cumulative volume of flow at Fulton during the period 16 February-10 March was 5,628,000 acre-feet which is equivalent to 2.3 inches of runoff from the contributing drainage area above Fulton. Of the total volume, 4,359,000 acre-feet originated in the drainage area between the site of Denison Dam and Fulton, and is equivalent to 6.5 inches of runoff from that drainage area. From the drainage area between Fulton and Alexandria, runoff for the period 18 February to 23 March was about 1,284,500 acre-feet which is equivalent to 1.6 inches of runoff. Runoff at Alexandria during the period 18 February to 23 March for the drainage basin between the site of Denison Dam and Alexandria amounted to about 5,643,500 acre-feet which is equivalent to 3.8 inches of runoff.

(2) February-May 1945. The flood was produced by storms centered over the basin during the period February-April. The principal storm periods were, in the upper portion of the basin, 19-28 February, 11-19 March, and 29-31 March, and in the lower portion 28 March-2 April. Light rainfall during the intervening periods contributed to the prolongated flood conditions through April and into May. Average precipitation during the first period in the upper basin amounted to about 7 inches, with a maximum of 8 to 9 inches in Boggy Creek and Little River Watersheds. Precipitation during the second period varied from about 7 inches over the Blue River Watershed to about 4 inches in the Kiamichi River Basin and about 6 inches in the Little River Basin. Precipitation during the third period varied from 3 to 4 inches immediately below Denison Dam to about 13 inches at Fulton. The fourth period produced an average of about 7.5 inches of precipitation over the lower portion of the basin, with a maximum of 15.3 inches near the boundary of the Cypress Creek and Sulphur River Watersheds. The peak discharges at gaging stations along Red River in the lower basin exceeded those of the

1938 flood, while those in the upper basin were smaller. Peak stages and flows for the 1945 flood at major gaging stations along Red River are shown below:

Station	Stage (feet)	Flow (c.f.s.)	Date
Arthur City	21.3	80,000	2/22/45
Index	28.1	152,000	4/ 1/45
Fulton	37.5	262,000	4/ 2/45
Shreveport	38.3	303,000	*
Alexandria	45.2	233,000	4/16-18/45

*Peak flow occurred on 4/5/45 and the peak stage occurred on 4/7/45.

The volume of inflow into Denison Reservoir during the period 14 February-14 April was 2,800,000 acre-feet. Runoff at Fulton during the period 13 February through 14 April for the drainage area between Denison Dam and the Fulton gage was 11,590,000 acre-feet, which is equivalent to 17.2 inches of runoff for that drainage area. Runoff from the drainage area between the Fulton gage and Alexandria gage for the period 23 February to 9 May was 14,218,000 acre-feet which is equivalent to 17.6 inches of runoff. Runoff at Alexandria, excluding flows from Denison Dam, during the period 23 February to 9 May was 25,808,000 acre-feet which is equivalent to 17.4 inches of runoff from the basin below Denison Dam.

(3) April-June 1957. Major storms centered in the northwestern portion of the basin during the period April-June produced this flood. During the period 19 April to 4 May, an average of 9.6 inches of rainfall occurred over the Red River Watershed above Fulton including the contributing drainage area above Denison Dam. The area above Denison Dam received 9.3 inches and the area between Denison Dam and Fulton received 10.3 inches. Below Fulton, the average rainfall for the period was 8.8 inches, with a maximum rainfall of 12.5 inches occurring in the Cypress-Red Chute Bayou Watershed. A second period of heavy rainfall occurred 22 May to 26 May averaging 2.8 inches over the basin above Fulton, with 2.1 inches of rain above Denison Dam and 5.2 inches between Denison and Fulton. Rainfall which occurred over the Red River Watershed above Denison Dam from 29 May to 5 June averaged 3.8 inches. Intermittent rainfall during the period 1 April to 30 June contributed sufficient runoff in the lower portion of the basin to maintain high stages during the period. Peak stages and flows for major gaging stations along the river are as follows:

Station	Stage (feet)	Flow (c.f.s.)	Date
Arthur City	28.4	136,000	6/6/57
Index	28.6	154,000	6/8/57
Fulton	31.1	228,000	6/9/57
Shreveport	33.9	230,000	5/3/57
Alexandria	40.7	197,000	*

*Peak flow occurred on 5/7/57 and the peak stage occurred on 5/13/57.

The volume of inflow into Denison Reservoir during the period 1 April through 30 June amounted to about 8,364,000 acre-feet which is equivalent to 4.6 inches of runoff from the contributing drainage area. Runoff at Fulton for the period 1 April through 30 June was 19,719,000 acre-feet; thus, the runoff between Denison Dam and Fulton was 11,355,000 acre-feet, which is equivalent to about 16.8 inches of runoff from that area. Runoff between Fulton and Alexandria for the same period was 4,323,000 acre-feet, which is equivalent to 5.4 inches of runoff from the contributing area. Runoff at Alexandria for the basin between Denison Dam and Alexandria during the period was 18,782,000 acre-feet which is equivalent to 12.7 inches of runoff.

(4) April-May 1958. A storm centered over northwest Louisiana, southwest Arkansas, and northeast Texas, produced this flood. The maximum precipitation of 20.9 inches occurred at Haynesville, Louisiana, in the Bayou Dorcheat Watershed. Stamps, Arkansas, in the Bayou Bodcau Watershed, and Daingerfield, Texas, in the Cypress Creek Watershed recorded 20.1 and 18.1 inches of rainfall, respectively. The average rainfall over the upper portion of the basin between Denison Dam and Fulton was 8.78 inches for the period 26 April-3 May with recorded rainfalls of 13.96 at Foreman, Arkansas, 13.73 inches at Ashdown, Arkansas, and 13.80 inches at DeKalb, Texas. In the basin area below Fulton, the average rainfall for the period 25 April-5 May was 9.9 inches. Peak stages and flows for major gaging stations along Red River are shown below:

Station	Stage (feet)	Flow (c.f.s.)	Date
Arthur City	26.4	120,000	5/ 3/58
Index	25.3	145,000	5/ 6/58
Fulton	29.4	214,000	5/ 6/58
Shreveport	33.7	249,000	5/ 8/58
Alexandria	40.1	200,000	5/12/58

The volume of inflow into Denison Reservoir during the period 28 April-17 May was 712,500 acre-feet. Runoff at Fulton during the

period 28 April-17 May was 4,477,100 acre-feet. Of the total volume 3,973,600 acre-feet was contributed by the drainage area between Denison Dam and Fulton and is equivalent to 5.9 inches of runoff from that drainage area. Runoff from the drainage area between Fulton and Alexandria during the period 25 April-24 May was 3,879,000 acre-feet which is equivalent to 4.8 inches of runoff. Runoff at Alexandria for the basin between Denison Dam and Alexandria during the period 25 April-24 May was 7,852,400 acre-feet which is equivalent to 5.3 inches of runoff.

b. Floods on tributaries.

(1) Blue River - Blue, Oklahoma, gage.

(a) February 1938. The record maximum stage at the Blue, Oklahoma, gage was produced by the storm of 14-18 February. Average rainfall during the storm period totaled 6.83 inches over the Blue River Watershed. On 15, 16, and 17 February, averages of 0.84 inch, 2.70 inches, and 2.51 inches, respectively, were recorded, with the remaining 0.78 inch occurring on 14 and 18 February. The precipitation was greatest in the upper portion of the basin, averaging 7.31 inches over the watershed above the gage. Sulphur and Ada, Oklahoma, located near the upper limits of the watershed, recorded total rainfalls of 9.25 inches and 8.50 inches, respectively, with Ada receiving 3.30 inches on 14 February and Sulphur receiving 4.85 inches on 16 February. Durant recorded a total of 5.68 inches of precipitation, with 3.15 inches on 17 February. The maximum stage of 31.81 feet was recorded at the Blue gage on 17 February when the discharge was 34,400 c.f.s. The total volume for the period 16-22 February amounted to 113,300 acre-feet, which is equivalent to 4.5 inches of runoff.

(b) April 1942. The storm of 23-28 April, which averaged 5.48 inches of rainfall over the Blue River Basin, produced the April flood. Tishomingo, near the western part of the basin, recorded 6.96 inches of rainfall for the 6-day period, of which 4.23 inches occurred on 24 April. A peak stage of 31.69 feet was recorded at the Blue gage on 25 April with a corresponding discharge of 33,600 c.f.s. This is the second highest flood of record at the Blue gage. A flood volume of 97,730 acre-feet, which is equivalent to 3.8 inches of runoff, was recorded for the period 23-28 April.

(c) June 1945. The storm of 16-18 June, which averaged 4.99 inches of rainfall over the Blue River Basin, produced the third highest flood of record. This storm was preceded by general rainfall on 7-12 June which averaged 4.59 inches over the watershed. Precipitation was most intense on 17 June, averaging 4.06 inches over the basin on that date. Durant received 6.20 inches on 17 June and a total of 7.59 inches for the 3 days, 16-18 June. A maximum stage of 31.35 feet, which corresponds to a discharge of 28,900 c.f.s., was

recorded at the Blue gaging station on 17 June. The flood volume from 17-22 June, inclusive, was 94,700 acre-feet, which is equivalent to 3.7 inches of runoff. The volume from 12-22 June, inclusive, was 130,600 acre-feet or 5.1 inches of runoff.

(2) Boggy Creek - Caney and Farris, Oklahoma, gages.

(a) February-June 1945. The floods experienced in the Boggy Creek Basin during the period 12 February-23 June were caused by a series of moderate to intense periods of precipitation interspersed among intermittent periods of light rain and no rainfall. The storms extended over the lower Red River Watershed and resulted in the largest flood volume of record at Fulton, Arkansas, 197 miles below the mouth of Boggy Creek. The precipitation for the total storm period amounted to about 39.48 inches, of which 8.15, 9.46, 5.00, 4.27, and 12.60 inches occurred during the respective months of February through June. During the interval February-June, seven periods of intense precipitation occurred as follows: 19-21 February, 3.78 inches; 25 February-6 March, 4.08 inches; 11-19 March, 5.46 inches; 28 March-4 April, 3.60 inches; 11-16 April, 3.14 inches; 9-16 May, 4.24 inches; and 2-18 June, 12.00 inches. The first five periods of intense rainfall, 19 February-16 April, were integral parts of large general storms over the lower Red River Basin, while the latter periods involved localized storms in the vicinity of Boggy Creek Basin. Records at the gaging stations in the basin show that the major streams in the basin were above flood stage about 40 percent of the period 20 February-23 June. Maximum stages of 25.20 feet on 18 June and 44.94 feet on 17 June were recorded on the Clear Boggy Creek, Caney and Muddy Boggy Creek, Farris gages, respectively, with corresponding peak discharges of 31,100 and 61,900 c.f.s. The flood volumes for the Clear Boggy Creek station amounted to 240,700 acre-feet from 4 through 26 June, and 446,200 acre-feet for the period 4 through 29 June at the Muddy Boggy Creek gage. These volumes are equivalent to 6.2 and 7.7 inches of runoff, respectively, from the drainage basin above the gages. For the period 20 February through 19 May, flood volumes past the Clear Boggy and Muddy Boggy Creeks stations amounted to 726,100 and 1,108,000 acre-feet, respectively, which is equivalent to 18.9 inches and 19.1 inches of runoff from the respective drainage areas.

(b) February 1938. The second largest flood of record in the Boggy Creek Basin was caused by two periods of precipitation, 20-24 January and 14-18 February, with practically no rainfall recorded in the intervening period. About 4 inches of precipitation fell in the Boggy Creek Basin during the first period, and minor flooding occurred on tributaries to Boggy Creek for a comparatively few days. During the period 14-18 February, average rainfall over the basin totaled 8.44 inches. About 2.70 and 2.80 inches of rainfall occurred on 16 and 17 February, respectively. Total

precipitation at Coalgate, near the center of the basin, was about 9.02 inches, of which 3.50 inches were recorded on 16 February. Precipitation at Ada, near the upper limits of the basin, amounted to about 8.50 inches, of which 3.30 inches occurred on 14 February. The Calvin, Oklahoma, precipitation station, located north of the upper limits of Muddy Boggy Creek watershed, recorded a total of 11.00 inches, of which 4.00 inches were experienced on 15 February. A maximum stage of 43.1 feet occurred at the Muddy Boggy Creek, Farris gaging station on 17 February. For the period 15-25 February, the peak discharge at the Farris gaging station was 52,500 c.f.s., with a total flood volume of 438,000 acre-feet, which is equivalent to 7.6 inches of runoff from the drainage area. Records indicate that major streams in the basin were above flood stage for 7 days. This flood was a major contributor to the peak discharge of record at the Fulton, Arkansas, gage on Red River.

(c) April 1942. The third largest flood of record in the Boggy Creek Basin was caused by runoff from the storm of 23-28 April. During this period, an average of 6.18 and 6.68 inches of rainfall occurred above the Caney and Farris stream gages on the Clear Boggy and Muddy Boggy Creeks, respectively. Precipitation at Coalgate, near the center of the basin, totaled about 7.45 inches, of which 4.40 inches occurred on 25 April. Maximum stages of 42.19 feet and 26.8 feet, with corresponding peak discharges of 41,200 c.f.s. and 52,800 c.f.s., were recorded at the Farris and Caney gages, respectively. From 23-30 April, the flood volume passing the Farris gage amounted to 354,900 acre-feet, which is equivalent to 6.1 inches of runoff from the drainage area.

(3) Kiamichi River - Belzoni, Oklahoma, gage.

(a) February-June 1945. During the period 11 February-18 June, periodic concentrations of rainfall produced excessive runoff from the Kiamichi River Basin, and flooding conditions were obtained on the Kiamichi River and Red River downstream during much of the period. The total precipitation during this time averaged 44.44 inches over the Kiamichi River Basin, with averages of 10.15 inches, 10.52 inches, 3.75 inches, 6.77 inches, and 13.25 inches for the respective months of this period. There were five periods of concentrated rainfall over the basin, namely, 19-21 February, 25-28 February, 28-30 March, 10-16 May, and 6-18 June, with corresponding averages of 4.37 inches, 3.10 inches, 3.53 inches, 6.13 inches, and 12.43 inches. During the period of maximum rainfall, 6-18 June, the rainfall was extremely intense on 17 June, with 7.95 inches, 3.60 inches, 3.03 inches, and 3.00 inches being recorded at Daisy, Spencerville, Antlers, and Hugo, respectively. The maximum stage of 43.90 feet and the corresponding discharge of 70,600 c.f.s., which is the second highest of record, was recorded at the Belzoni gage on 17 June. The volume during the period 8-26 June amounted to 725,200 acre-feet, which is equivalent to 9.6 inches of runoff. The

flood volume at the Belzoni gage during the period 12 February-26 June was 2,511,000 acre-feet, which is equivalent to 33.1 inches of runoff. The Kiamichi River was above flood stage at the Belzoni gage about 24 days during the period 11 February-25 June. Kiamichi River contributed about 12 percent of the total flood volume which passed the Fulton, Arkansas, gaging station on Red River during the period 14 February-8 May.

(b) February 1938. Two periods of intense precipitation which occurred on 20-24 January and 14-18 February caused extensive runoff in the Kiamichi River Basin. The 5-day storm of 20-24 January produced an average rainfall of 5.34 inches over the basin, with 2.60 inches on 21 January. Antlers recorded 3.58 inches of rainfall on 21 January. The second period, 14-18 February, produced an average rainfall over the basin of 7.20 inches, with an average of 3.86 inches on 17 February. On 17 February, Antlers and Tuskahoma received 4.25 inches and 3.94 inches of rainfall, respectively. A maximum stage of 44.0 feet, which produced a peak discharge of record of 71,400 c.f.s., was recorded at the Belzoni gage on 18 February. The Kiamichi River was above flood stage at the Belzoni gage about 7 days. The volume from 15-28 February was 513,100 acre-feet, or an equivalent of 6.8 inches of runoff. The flood volume at the Belzoni gage for the period 21-30 January was 276,600 acre-feet, which is equivalent to 3.7 inches of runoff.

(c) January 1949. The third largest flood of record at the Belzoni gage resulted from the storm of 22-27 January, with an average rainfall over the basin of 9.34 inches. Kiamichi Tower, in the eastern part of the basin, reported 11.63 inches of rainfall for the 6-day period, of which 5.79 inches occurred on 24 January. At the gage, this storm produced a peak stage of 42.93 feet, which corresponds to a discharge of 67,200 c.f.s. A flood volume of 566,500 acre-feet passed the Belzoni gage, which is equivalent to 7.5 inches of runoff from the contributing area.

(4) Sulphur River. Precipitation data are available at Paris, Sulphur Springs, Greenville, Clarksville, Naples, and Mount Pleasant, Texas, for periods of 85, 75, 67, 62, 58, and 49 years, respectively. Fragmentary records of rainfall and stage data indicate floods occurred in April and May 1915, and May 1930. More detailed records subsequent to 1937 show major flooding occurred in 5 years during the period 1938 through 1967. These five floods are discussed below.

(a) January 1938. The storm of 19-24 January, centered over Naples, Texas, produced this flood. Prior to the storm, intermittent rainfalls over the period 1-18 January amounted to 0.58 inch at Mount Pleasant, 0.51 inch at Sulphur Springs, and 0.24 inch at Naples. The precipitation recorded at the storm center was 10.7 inches. Total rainfall over the watershed above Darden, Texas, averaged 6.7 inches and produced a maximum discharge

of 92,900 c.f.s. with a peak stage of 35.4 feet at Darden. Total runoff for the watershed was 5.8 inches, or 850,000 acre-feet.

(b) March-April 1945. This flood was produced by the storm of 28-30 March which was centered over the southeast portion of the watershed above Darden. Prior to the storm, rainfall of 5.21 inches at Mount Pleasant, 4.94 inches at Sulphur Springs, and 5.68 inches at Naples occurred intermittently over the period 1-27 March. The storm occurred over a period of about 48 hours with maximum recorded rainfalls of 11.4 inches at Mount Pleasant, 11.3 inches at Sulphur Springs, and 11.0 inches at Naples. The average rainfall over the watershed totaled 8.6 inches and produced a runoff of 8.1 inches, or 1,185,000 acre-feet. The maximum discharge and peak stage at Darden were 157,000 c.f.s. and 37.6 feet, respectively.

(c) April-May 1957. The storm of 19 April through 4 May, centered over Wolfe City, Texas, produced this flood. Prior to the storm, rainfall at Mount Pleasant, Sulphur Springs, and Naples was 3.27, 3.22, and 5.50 inches, respectively, and occurred intermittently during the period 1-18 April. The precipitation recorded at the storm center was 11.2 inches. The minimum rainfall recorded was 6.5 inches at Naples. The watershed above Texarkana Dam had an average of 9.8 inches of rain and the area below the dam had an average of 8.2 inches. The storm produced a peak pool elevation at Texarkana Dam of 250.33 feet with a peak inflow of 75,952 c.f.s.

(d) April-May 1958. The storm of 25 April-5 May, centered in the area of Texarkana Dam, produced this flood. Prior to the storm, rainfall at Mount Pleasant, Sulphur Springs, and Naples was 2.71, 2.93, and 2.96 inches, respectively, and fell intermittently over the period 1-24 April. Maximum rainfall was 16.9 inches at Texarkana Dam, and the minimum of 6.5 inches was recorded at Honey Grove, Texas. The average rainfalls for the watershed above and below Texarkana Dam were 10.5 inches and 16.5 inches, respectively. The peak pool elevation at Texarkana Dam was 249.79 feet with a peak inflow rate of 88,984 c.f.s.

(e) April-May 1966. The storm of 22 April-2 May, centered in the area of Wolfe City, Texas, produced this flood. Prior to the storm, rainfall at Sulphur Springs and Naples was 2.22 and 3.71 inches, respectively. The rainfall occurred intermittently over the period 1-21 April. The storm produced a maximum rainfall of 16.7 inches at Wolfe City and a minimum of 11.9 inches at Commerce, Texas. The average rainfall over the watershed was 14.5 inches. The peak pool elevation at Texarkana Dam reached 252.64 feet with a peak inflow rate of 126,490 c.f.s.

(5) McKinney Bayou. Precipitation data are available at Fulton, Index, Ravana, Stamps, and Texarkana, Arkansas, for 81, 31, 27, 26, and 84 years of record, respectively. Studies of U. S.

Weather Bureau records mentioned above are the only means of determining when headwater flooding may have occurred along McKinney Bayou prior to 1936. These studies indicate flooding probably occurred as a result of the storms of August 1915, October 1926, and May 1930. From 1937 to date, stage records at Kemps Bridge, Arkansas, on McKinney Bayou Canal, indicate flooding occurred in July 1940, April 1945, January 1950, April 1958, April 1964, and April 1966. In addition to flooding induced by headwater flows, flooding on McKinney Canal below Kemps Bridge may also result from backwater from Red River. The major floods of recent record, those of April-May 1958 and 1966, are described below.

(a) April-May 1958. The storm of 25 April to 5 May, centered at Stamps, produced this flood. Prior to the storm, for the period 1-24 April, rainfall at Fulton, Index, Ravana, Stamps, and Texarkana Airport was 2.16, 1.70, 1.90, 1.46, and 2.37 inches, respectively, and averaged 1.82 inches over the watershed. The storm produced an average of 12 inches of rainfall over the watershed, with a stage of 20.9 feet and estimated discharge of 8,000 c.f.s. at Kemps Bridge on 27 April. Additional precipitation fell on 1 through 4 May and the resulting runoff maintained high stages for several days. Total rainfall at Fulton, Index, Ravana, Stamps, and Texarkana was 12.78, 11.20, 18.36, 20.10, and 12.92 inches, respectively. The average rainfall over the watershed above Kemps Bridge for the period 25 April to 5 May was 14 inches. Available discharge data are not adequate for an accurate determination of runoff.

(b) April-May 1966. The storm of 20 April through 2 May produced this flood. Prior to the storm, rainfall amounted to about 1 inch over the watershed from the period 12-15 April. The average rainfall over the watershed above Kemps Bridge produced by the storm was 16 inches. Total rainfalls for the storm period at Fulton, Index, Ravana, Stamps, and Texarkana Airport were 18.59, 15.46, 15.31, 19.19, and 15.70 inches, respectively. A peak stage of 21.3 feet and estimated discharge of 9,000 c.f.s. at Kemps Bridge occurred on 27 April. Additional rainfall after 27 April prolonged flooding for several days. Available discharge data are not sufficient to make an accurate determination of runoff.

(6) Bodcau Bayou above Sarepta, Louisiana. Fragmentary hydrologic data indicate major floods occurred in June 1905 and May 1930, and stage records since October 1938 at Sarepta indicate major flooding occurred in May 1958. Minor flooding occurred during July 1940 and May 1966. The construction of Bayou Bodcau Dam and Reservoir, completed in 1949 by the Corps of Engineers, and improvements in tributary areas by the State of Louisiana, Department of Public Works, have modified peak stages and flows.

(a) April-May 1958. The storm of 25 April to 5 May, centered in the watershed, produced this flood. Prior to the storm, rainfall in the watershed averaged 1.7 inches for the period 1-24 April. Average rainfall over the watershed during the storm period was 18 inches. Total rainfall for the storm period was 20.1 inches at Stamps, and 14.7 inches at Taylor and Hope, Arkansas. The highest stages of record since improvements were made in the watershed occurred during this flood. The peak flow at Sarepta was 18,600 c.f.s. at a stage of 25.1 feet on 2 May. Runoff at Sarepta during the period 25 April-11 May was 316,510 acre-feet which is equivalent to 10.9 inches of runoff.

(b) April-May 1966. The storm of 21 April to 2 May produced this flood. Prior to the storm, rainfall over the watershed averaged 1.4 inches for the period 1-20 April. During the storm period average rainfall was 16.1 inches. Rainfall maximums recorded during the storm were 6.7 inches at Hope and 6.1 inches at Stamps, both on 24 April. The peak flow at Sarepta was 10,800 c.f.s. at a stage of 22.3 feet on 2 May. Runoff at Sarepta during the period 21 April-11 May was 194,400 acre-feet which is equivalent to 6.7 inches of runoff.

(7) Posten Bayou. Precipitation data are based on 76 years of continuous record at Plain Dealing, La. The maximum 1-day precipitation of 11.96 inches occurred in July 1920. The maximum 1-month precipitation of 18.82 inches occurred in July 1933. The two periods of high rainfall produced heavy runoff and high stages in the watershed; however, stage and discharge records were not obtained on Posten Bayou until 1956 and an accurate assessment of flooding for these two storms is not possible. Two other important storms, those of April-May 1958 and April-May 1966, are discussed below. Prior to the installation of staff and automatic gages 3 miles northeast of Wardview, Louisiana, on Posten Bayou, studies of rainfall records are the only means of determining when headwater flooding occurred. Based on these studies, additional floods are indicated to have occurred as a result of the storms of August 1915, May 1930, July 1940, and May 1946. Available depth-area data indicate that stages greater than 190.1 feet at the Wardview gage result in overflow at some locations along the stream.

(a) April-May 1958. The storm of 25 April-5 May, which was centered over Stamps, produced this flood. Prior to the storm, rainfall amounted to 1.4 inches at Plain Dealing, Louisiana, and was intermittent over the period 1-21 April. The maximum rainfall recorded was 20.1 inches at Stamps, while at Plain Dealing rainfall of 14.7 inches was recorded. The total rainfall over the watershed for the storm period averaged 16.5 inches and, on 1 May 1958 at Wardview, produced a stage of 199.0 feet with a maximum discharge of 2,389 c.f.s.

(b) April-May 1966. The storm of 21 to 26 April, centered over Gladewater, Texas, produced this flood. Prior to the storm, rainfall averaged 1.78 inches over the watershed and fell intermittently during the period 12-19 April. At Gladewater, 25.25 inches of rain was recorded, and at Plain Dealing, 6.34 inches was recorded. The total rainfall during the storm period averaged about 7.0 inches over the watershed and produced a maximum stage of 198.4 feet at Wardview on 26 April. An additional 5 inches of rain fell during the period 3-6 May, and stages remained at bankfull until 10 May.

(8) Twelvemile Bayou. Precipitation data are available at Shreveport, La., Longview, Marshall, Naples, and Jefferson, Texas, for a period of 95, 86, 59, 59, and 55 years, respectively. Subsequent to 1942, gage and discharge records are available for the U. S. Geological Survey station on Twelvemile Bayou near Dixie, Louisiana. Records of rainfall and stage data indicate floods occurred in the Cypress-Twelvemile Bayou watershed in May 1930, May 1944, March-April 1945, May-June 1946, February 1950, May-June 1953, April-May 1957, April-June 1958, and April-May 1966. The three largest floods are discussed below. Gage readings and discharge data refer to Twelvemile Bayou near Dixie, Louisiana.

(a) March-April 1945. The storm of 29 April through 10 May produced this flood. Prior to the storm, rainfall at Gilmer, Jefferson, and Mount Pleasant, Texas, was 6.41, 8.79, and 5.21 inches, respectively, and occurred intermittently over the period 2-26 March. The storm produced a maximum rainfall of 17.2 inches at Winnsboro, Texas, during a 48-hour period. The average rainfall over the watershed was 10.8 inches with a maximum discharge of 34,900 c.f.s. and peak stage of 35.6 feet at Dixie. Runoff from the watershed above Dixie amounted to 1,207,170 acre-feet or 7.2 inches of runoff.

(b) April-June 1958. The storm of 25 April through 8 June produced this flood. Prior to the storm, rainfall amounted to 2.1, 1.7, and 2.7 inches at Gilmer, Jefferson, and Mount Pleasant, Texas, respectively, and was intermittent over the period 1-24 April. The storm produced a maximum rainfall of 20.7 inches at Daingerfield, Texas, with 10.0 inches falling in a 48-hour period. The watershed had an average of 15.7 inches of rain during the storm period. With Ferrells Bridge Dam in partial operation, the stage at Dixie reached 35.7 feet, the maximum of record. The resultant peak discharge was 38,400 c.f.s., and the runoff from the watershed was computed to be 10.3 inches or 1,726,720 acre-feet for the period 25 April-15 June.

(c) April-May 1966. The storm of 21 April through 2 May produced this flood. Prior to the storm, rainfalls at Gilmer, Jefferson, and Mount Pleasant, Texas, were 1.85, 1.54, and 2.41 inches, respectively. These rainfalls occurred intermittently over

the period 1-20 April. The maximum rainfall of 25.25 inches, of which 18 inches fell in 48 hours, occurred at Gladewater, Texas, which is just outside the watershed. Within the watershed Harleton and Ferrells Bridge Dam, Texas, recorded total precipitation accumulations of 24.50 and 23.92 inches, respectively, and over 15 inches occurred at both locations in 48 hours. The average rainfall for the watershed during the storm period was 17.8 inches. The maximum stage was 32.7 feet with a peak flow of 31,400 c.f.s. If conditions in the watershed were the same as those which existed during the 1958 storm (Ferrells Bridge Dam under construction and not in full operation), it is estimated that the stage would have exceeded that of the 1958 flood. Runoff for the watershed during the period 21 April-30 June was 9.8 inches, or 1,636,600 acre-feet.

(9) Maniece Bayou. Precipitation data are available at Fulton, Stamps, Texarkana, and Taylor, Arkansas, for 82, 26, 20, and 24 years of record, respectively. Studies of U. S. Weather Bureau records mentioned above are the only means of determining when headwater flooding may have occurred along Maniece Bayou prior to 1956. The studies indicate flooding probably occurred as a result of storms of August 1915, May 1930, July 1933, June-July 1940, and May 1946. From 1956 to date, stage records at Canfield, Arkansas, on Maniece Bayou indicate flooding occurred in April-May 1957, April-May 1958, and April 1966. The major floods of April-May 1958 and 1966 are described below.

(a) April-May 1958. The storm of 25 April to 5 May produced this flood. Prior to the storm, rainfall occurring intermittently over the period 1-24 April amounted to 2.11 inches at Fulton, 1.46 inches at Stamps, and 2.37 inches at Texarkana Airport. Rainfall over the watershed during the storm period averaged 18.7 inches and produced the highest stage of record, 220.0 feet, at Canfield, Arkansas, on 3 May. An accurate determination of runoff is not possible because of the effects of Red River backwater.

(b) April-May 1966. The storm of 20 April through 3 May produced this flood. Prior to the storm, rainfall during the period 1-19 April amounted to 2.01 inches at Fulton, 1.27 inches at Stamps, and 1.89 inches at Texarkana Airport. The total rainfalls for the storm period at Fulton, Stamps, and Texarkana Airport were 18.59, 19.19, and 15.70 inches, respectively. The maximum discharge at Canfield, Arkansas, was 1,160 c.f.s. occurring at a stage of 216.78 feet. An accurate determination of runoff is not possible because of the effects of Red River backwater.

(10) Bayou Dorcheat near Minden, Louisiana. Gage records indicate that major floods occurred on Bayou Dorcheat in May 1930, July 1933, May 1944, May 1957, April 1958, and May 1966. The major storm of record occurred in April 1958.

(a) April-May 1958. The storm of 23 April to 10 May produced this flood. Prior to the storm, rainfall averaged 1.2 inches over the watershed during the period 1-22 April. Average rainfall during the storm period was 16.5 inches. The maximum 1-day rainfall was 9.0 inches at Stamps, Arkansas, on 27 April. At the towns of Magnolia and Haynesville, Louisiana, rainfalls of 7.9 inches and 7.5 inches were recorded on 27 April and 26 April, respectively. The peak flow at Minden, Louisiana, was 44,800 c.f.s on 1 May at a stage of 24.9 feet. Runoff for the watershed above Minden during the period 25 April-23 May was 728,000 acre-feet which is equivalent to 12.5 inches of runoff.

(b) April-May 1966. The storm of 21 April to 2 May produced this flood. Prior to the storm, rainfall averaged 1.4 inches over the watershed during the period 1-20 April. Average rainfall during the storm period was 11.9 inches. The maximum 1-day rainfall was 6.7 inches at Hope and 6.1 inches at Stamps, both on 24 April. The peak flow at Minden, Louisiana, was 16,600 c.f.s. at a stage of 19.9 feet on 5 May. Runoff for the watershed above Minden during the period 22 April-21 May was 333,000 acre-feet or 5.7 inches of runoff.

(11) Bayou Pierre at Lake End, Louisiana. Rainfall and streamflow data indicate that flooding on Bayou Pierre occurred during the storms of August 1933, November 1940, April 1945, April-May 1953, and September 1958. The greatest flood of record was produced by the storm of April 1945. Backwater from Red River affects the stages and discharges on Bayou Pierre. Therefore, volumetric determinations of runoff cannot be made for this location.

(a) August 1933. The storm of 22-28 July produced this flood. Prior to the storm, rainfall averaged about 6 inches over the watershed during the period 1-21 July. Average rainfall during the storm period was 15.5 inches. At Shreveport, a 1-day rainfall of 12.1 inches occurred on 24 July. The peak stage of 45.8 feet was based on a high water mark obtained in early August.

(b) April-May 1945. The storm of 31 March to 4 April produced this flood. Prior to the storm, rainfall averaged 7.1 inches over the watershed during the period 1-30 March. The average rainfall during the storm period was 6 inches. The maximum 1-day rainfalls were 5.5 inches at Robeline, Louisiana, and 3.4 inches at Grand Cane, Louisiana, both occurring on 1 April. Stages exceeding 30.9 feet prevailed throughout the month of March. Stages rose rapidly in April to an estimated 47.3 feet, based on a high water mark at Lake End on 3 April. During the storm period, the main stem of Red River was experiencing record stages, and stages in Bayou Pierre remained above normal for an additional month.

(c) April-May 1953. Storms which occurred in April and May produced this flood. Two periods of intense rainfall occurred during 23 April-4 May and 10-19 May. Prior to the first storm, rainfall averaged 10.1 inches over the watershed during the period 1-22 April. Rainfall during the first and second storm periods averaged 10.5 and 8.5 inches, respectively. The maximum 1-day rainfall for each period was 8.4 and 3.5 inches at DeSoto Fire Tower on 29 April and 17 May, respectively. Stages rose to 15.6 feet on 29 April, 38.1 feet on 6 May, and reached a peak stage of 41.5 feet on 20 May. A discharge of 9,690 c.f.s. was measured at a stage of 41.4 feet on the previous day.

(12) Saline Bayou near Clarence, Louisiana. Rainfall and streamflow records indicate that major floods occurred on Saline Bayou in July 1933, April 1945, June 1950, May 1953, June 1957, and May 1958. Based on rainfall data, the storm of 22-27 July 1933 with an average rainfall of 13.5 inches produced the greatest headwater flood of record. The storm of April 1945 produced the highest stages; local residents estimated the crest to be 43.6 feet. However, the basin received only 6 inches of rainfall during the storm, and the flooding resulted mainly from backwater from Red River. A major headwater flood of record occurred in May 1953, and a significant combined headwater-backwater flood was experienced in April-June 1958. These floods are described below.

(a) April-May 1953. Two periods of intense rainfall occurring on 23 April-4 May and 11-19 May caused this flood. Prior to the first rainfall period, the average rainfall during the period 1-22 April was 2.2 inches. Total rainfall from 23 April to 19 May was 20.5 inches. Maximum rainfall in each period was 9.1 inches on 29 April, and 8.9 inches on 18 May at Gum Springs, Louisiana. Other stations with high rainfall were Homer, Louisiana, with 5.8 inches on 29 April and Ashland, Louisiana, with 6.2 inches on 17 May. On 19 May the peak flow at Clarence was 14,200 c.f.s. at a stage of 40.7 feet. Runoff for the watershed above Clarence during the period 23 April-28 June was 899,000 acre-feet which is equivalent to 12.2 inches of runoff.

(b) April-June 1958. The storm of 28 April to 10 June and Red River backwater caused this flood, with the latter being the primary cause. On 11 May prior to the storm, records indicate a maximum reverse flow of 6,750 c.f.s. occurred at a stage of 37.5 feet. During the storm period average rainfall of 7.8 inches over the watershed produced a peak flow of 8,880 c.f.s. at a stage of 37.5 feet on 26 May. Runoff for the watershed above Clarence during the period 28 April-10 June was 273,000 acre-feet which is equivalent to 3.7 inches of runoff.

(13) Nantachie Creek near Montgomery, Louisiana. The largest flood of record occurred in April-May 1953. Another major flood occurred in February 1966. These floods are described below.

(a) April-May 1953. The storm of 28 April to 18 May produced this flood. Prior to the storm, total rainfall over the watershed during the period 1-27 April averaged 1.6 inches. During the storm, the total rainfall amounted to 29.3 inches and fell in the three periods, 28-29 April, 3-4 May, and 12-18 May, with no intervening rainfall. The amounts of rainfall occurring in the three periods were 11.1, 2.3, and 15.9 inches, respectively. The maximum 1-day rainfalls in each period were 6.5 inches on 28 April, 2.1 inches on 4 May, and 7.3 inches on 17 May. Peak flows in the order of their occurrence were 8,030 c.f.s. at a stage of 13.4 feet on 29 April, 2,060 c.f.s. at a stage of 10.2 feet on 13 May, and 10,500 c.f.s. at a stage of 14.7 feet on 17 May. Runoff for the watershed during the period 29 April-26 May amounted to 69,390 acre-feet or 27.7 inches of runoff.

(b) February 1966. The storm of 9-15 February produced this flood. Total rainfall preceding the storm was 0.3 inch which fell on 1 February. Rainfall over the watershed during the storm period averaged 10.5 inches with the maximum of 6.7 inches falling on 9 February. The peak flow of 6,944 c.f.s. occurred at a stage of 12.8 feet on 9 February. Runoff from the watershed during the period 9-25 February amounted to 22,370 acre-feet which is equivalent to 8.9 inches of runoff.

(14) Cane River. For the period prior to 1939, stream gaging records are not available and flooding was determined by analysis of rainfall data. Rainfall records are available for periods of 14 to 81 years, the longest being from the Alexandria, La., station with 81 years, followed by 61 years for Robeline, La., and 45 years for Natchitoches, La. Subsequent to 1938, daily gage and intermittent discharge records are available for the Cane River station at Galbraith, La., near the lower end of the basin. Due to backwater from Red River during major floods the stage-discharge relation is poorly defined. Flooding has occurred in July 1906, May 1910, March-April 1913, July 1933, May 1944, April 1945, February 1950, May 1953, May 1957, and May 1958. Two of the major floods are discussed below.

(a) April 1945. The storm of 30 April to 4 May, centered over Montgomery, Louisiana, produced this flood. Prior to the storm, rainfall over the watershed was above normal, averaging 2.5 inches during the period 17-28 February and 5.5 inches during the period 1-29 March. Montgomery received 7.7 inches of rainfall in the period 1-29 March, while Colfax, Natchitoches, and Kisatchie, Louisiana, recorded 6.6, 4.1, and 3.5 inches, respectively. During the storm period, 30 April-4 May, Montgomery recorded 9.2 inches of precipitation. Other stations in the watershed at Natchitoches, Colfax, and Kisatchie recorded 7.2, 6.4, and 6.2 inches of rainfall, respectively, over the same period. The storm produced an average precipitation over the watershed of 7.3 inches. High stages prevailed on Cane River at Galbraith from 17 February through the end of May. The maximum stage of 49.9 feet at Galbraith occurred on

16-18 April, while, at the mouth of Cane River near Colfax, the stage was 53.0 feet. Discharge measurements were not made in 1945.

(b) May 1953. The flood was produced by storms centered over Simpson, Louisiana, located just outside the lower end of the watershed, and over Robeline, Louisiana, in the watershed. The principal storm periods were 23 April through 4 May for the storm centered at Simpson and 12 May through 18 May for the storm centered at Robeline. Prior to the storms, rainfall over the watershed averaged 0.7 inch and occurred intermittently on 3 days during the period 1-22 April. Average precipitation depth during the first storm period amounted to 14.2 inches over the watershed, with Simpson receiving 18.0 inches and Montgomery, Colfax, Robeline, Natchitoches, and Grand Ecore recording 14.2, 13.2, 12.9, 12.4, and 11.9 inches, respectively. During the second storm period, the average rainfall was 16.5 inches, with a maximum rainfall of 18.9 inches at Robeline. Stations at Natchitoches, Montgomery, Simpson, and Colfax recorded 16.2, 15.9, 15.8, and 15.6 inches of rainfall, respectively. High stages on Cane River were obtained from 29 April through 15 June. Rainfall from the first storm series produced a peak stage at Galbraith of 41.2 feet and a corresponding discharge of 6,230 c.f.s. on 6 May. The maximum stage at Galbraith of 47.7 feet occurred on 23 May. The discharge corresponding to the peak stage was not observed because of Red River backwater.

(15) Bayou Rigolette near Pineville, Louisiana. Records indicate that major flooding on Bayou Rigolette occurred in February 1950, May 1953, June 1957, and May 1958. The major flood of record occurred in May 1953. Data for the floods of 1950 and 1953 follow.

(a) February 1950. Intense rainfall over the watershed during February produced this flood. For the period 9-14 February, average rainfall over the watershed was 8.8 inches. During this period, Colfax, Louisiana, received 9.9 inches with a maximum 1-day rainfall of 3.8 inches on 13 February, Winnfield, Louisiana, received 9.2 inches with a maximum 1-day rainfall of 4.3 inches on 13 February, and Pollock, Louisiana, received 9.2 inches with a maximum of 4.0 inches on 12 February. Between 15-21 February there was no measurable rainfall. During the period 12-22 February, the average rainfall over the watershed was 1.7 inches. Maximum rainfall during this period was 2.6 inches at Winnfield, 2.3 inches at Gum Springs Tower, and 1.7 inches at Pineville on 22 February. The peak flow at Pineville resulting from this rainfall was estimated to be in excess of 6,500 c.f.s. at a stage of 83.9 feet on 23-24 February.

(b) April-May 1953. The storm of 24 April to 19 May produced this flood. Prior to the storm, rainfall over the watershed averaged 0.9 inch during the period 1-23 April. Rainfall during the storm was concentrated in the periods 24 April-4 May and 11-19 May. Total rainfall during the storm was 30.5 inches with maximum rainfalls of 12.8 inches and 11.1 inches occurring at Pollock, Louisiana, on 29 April and 17 May, respectively. Gum Springs, Louisiana, recorded 9.1 and 8.9 inches on 29 April and 18 May, respectively. Near Colfax, Louisiana, about 30 miles upstream of the Pineville gage the peak flow was 7,279 c.f.s. at a stage of 30.6 feet on 21 May. At Pineville, the peak flow was estimated to be in excess of 9,000 c.f.s., based on a high water mark of 88.3 feet which occurred between 21-27 May.

17. GROUND WATER

a. Availability and quality. The general availability of ground water in the Red River Basin is shown in figure 4. On this map, the basin has been divided into four regions based on the quantity of fresh ground water available (water that contains less than 1,000 p.p.m. of dissolved solids). To facilitate discussion, these four regions have been further subdivided into subregions or areas. Information shown in figure 4 indicates the depths and yields of wells, and the depth to water in the wells that tap the principal aquifers. The well yields are based on information from municipal, industrial, or irrigation wells, and in some instances from test wells. The yields (shown in Fig. 4) are not to be regarded as indexes of the capability of all wells in an area, but as indications of the magnitudes of the yields presently (1967) obtained from the aquifers. Discussion of ground water conditions in each region follows.

Region 1. This region embraces the area along the main stem of the Red River in which alluvial deposits represent the principal source of ground water.

Along the Texas-Oklahoma state line, yields of 500 g.p.m. are possible under optimum conditions. Yield as high as 1,000 g.p.m. and 1,700 g.p.m., respectively, may be expected from wells that tap the alluvial deposits in Arkansas and Louisiana. Yields of 2,800 g.p.m. have been reported in Louisiana from test wells in the alluvium. Static water levels in wells throughout the region generally are less than 25 feet below the ground surface. In most locations, maximum supplies of ground water are available from the alluvium immediately adjacent to the river.

Depth to water in the alluvium fluctuates from near ground surface to about 25 feet below the surface. Water-level fluctuations are caused primarily by changes in river stage, recharge from precipitation, and discharge by pumpage and evapotranspiration.

Throughout the region, ground water has a characteristically high degree of hardness, and contains excessive concentrations of iron. Hardness ranges from 250 to 700 p.p.m., and the iron content ranges from 2 to 15 p.p.m. In Texas and Oklahoma, ground water from the alluvium generally is suitable for public supply, irrigation, and some industrial uses. In Arkansas and Louisiana, water in the alluvium is unsuitable for municipal and industrial uses without treatment, but is suitable for irrigation.

Fresh water is available in most places in the region from the aquifers of Cretaceous or Tertiary age that underlie the alluvium. Because of the presence of connate salt water, however, little or no fresh water is available from the aquifers beneath the alluvium in McCurtain County, Okla., Little River County, Ark., and Red River and Natchitoches Parishes, La.

In the vicinity of Alexandria, moderate to large supplies of ground water are available from the sands of Miocene age which underlie the alluvium. These sands contain three highly productive fresh-water-bearing zones which are designated by their depth below Alexandria as the "400-foot" sand, the "700-foot" sand, and the "1,000-foot" sand. Wells that tap these sands have yields as high as 1,200 g.p.m. The water is suitable for many uses without treatment, but is generally unsuitable for irrigation because of high sodium content.

Region 2. The Sparta Sand is the principal source of ground water in this area. Wells generally are not more than 500 feet deep and some wells yield as high as 1,500 g.p.m. Static water levels range from 40 to 125 feet below land surface.

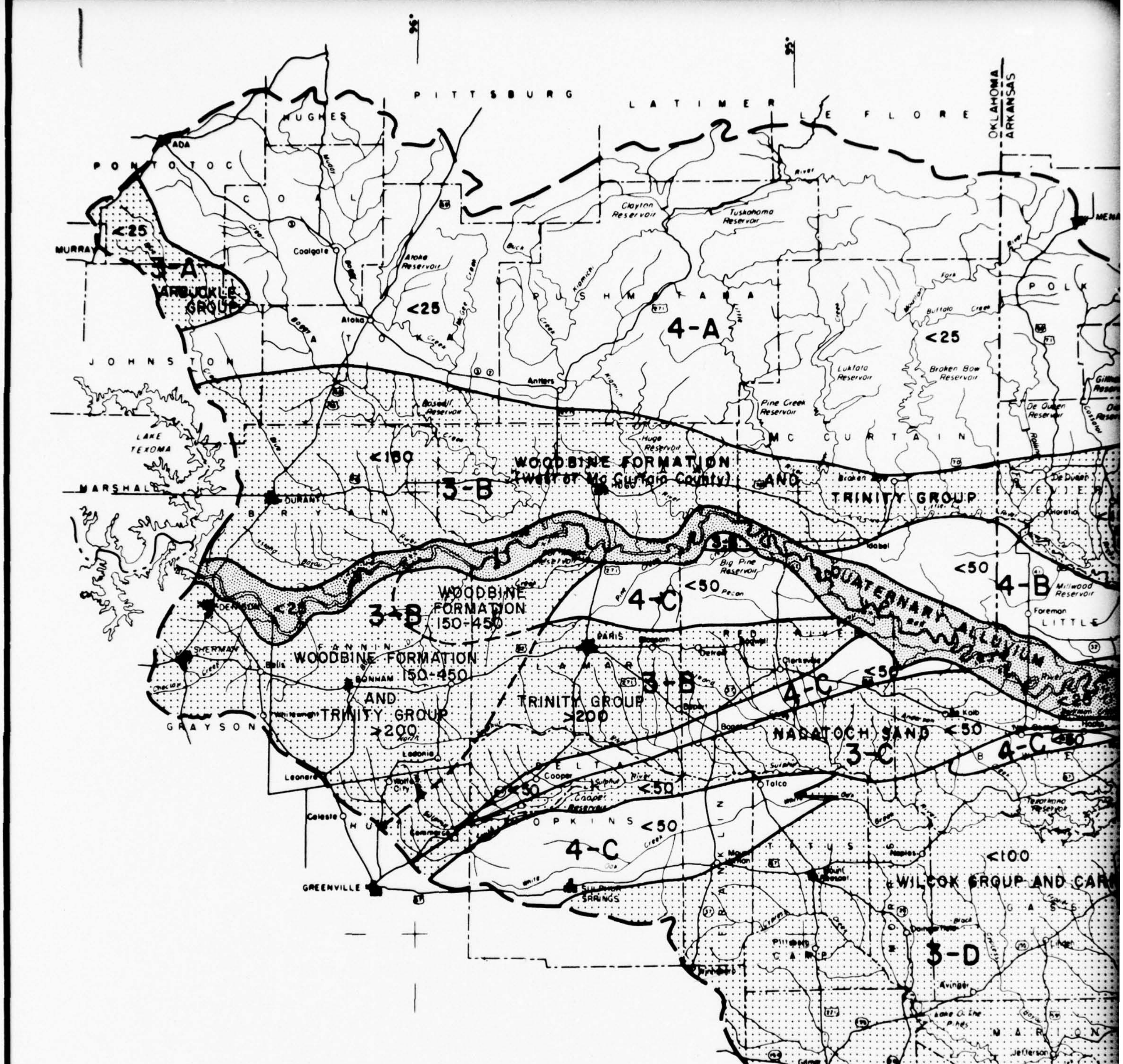
Water supplies from the Sparta Sand have been developed to a limited extent and are used primarily for domestic and stock watering purposes. Most of the wells are of small diameter and are constructed to yield less than 50 g.p.m.

Ground water in the area generally is a soft, sodium bicarbonate type. Iron exceeded the recommended limit of 0.3 p.p.m. in three of the five samples available, while the concentrations of other mineral constituents are within the limits recommended by the U. S. Public Health Service. The water generally is suitable for irrigation, public supply, and many industrial uses.

Region 3.

Area A. Limestone formations of the Arbuckle Group are the principal source of water to wells in the area. These formations yield water to springs and wells from fractures and solution channels. Commonly, the wells are artesian with adequate pressure to flow at the surface. Information currently available indicates that in some locations large supplies of ground water may be available in the Arbuckle Mountains. However, hydrologic and geochemical data are not sufficiently detailed to determine the extent to which these ground-water resources can be developed.

Several springs issue from the limestone formations, and provide a relatively stable base flow to the streams in the area. Byrds Mill Spring, the largest in the area, had a reported average yield in excess of 8 m.g.d. in 1962 (Westfall, 1963).



EXPLANATION

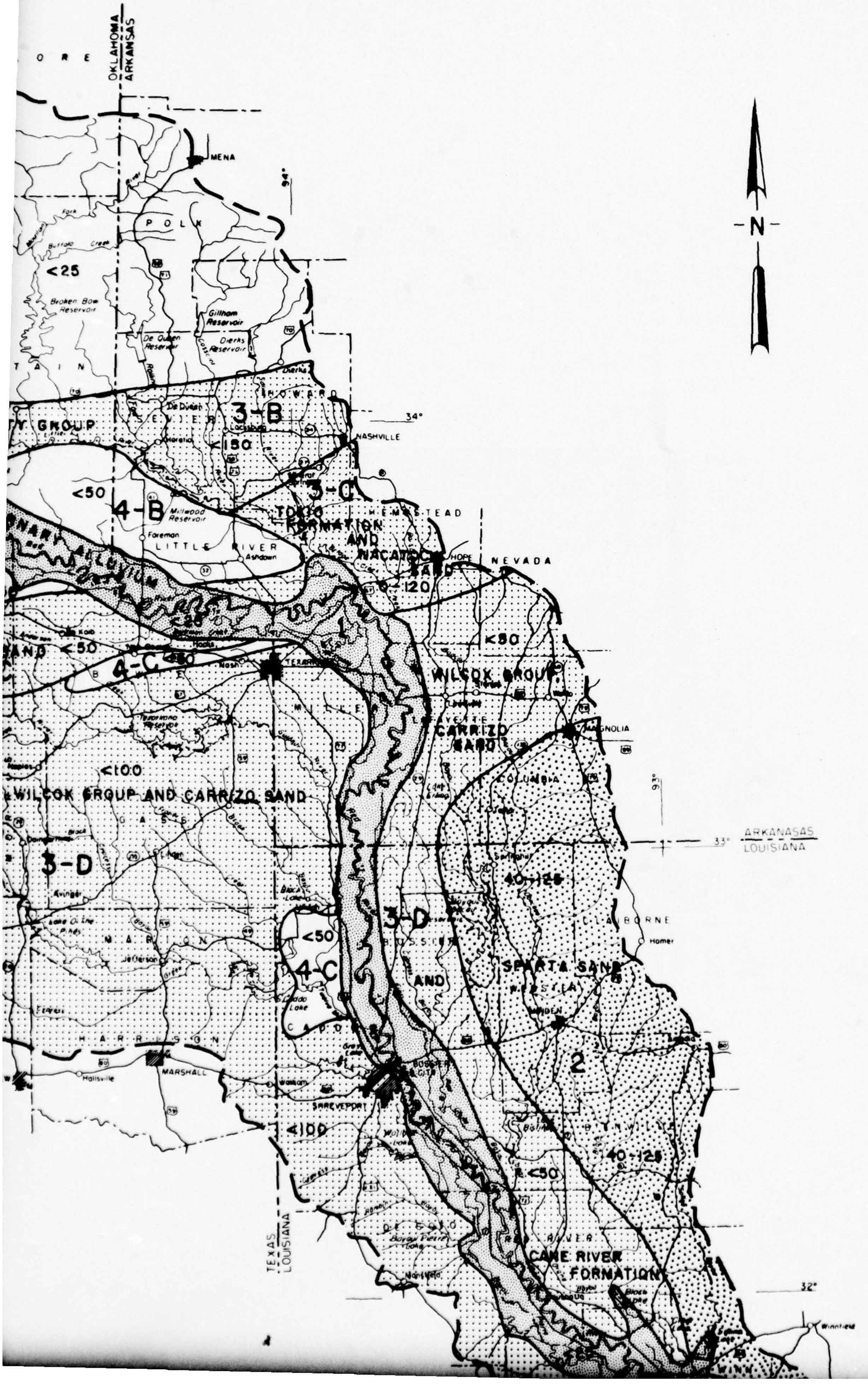
YIELD AND DEPTH OF WELLS

1	Well yields range from 500 GPM in Oklahoma and Texas to 1,700 GPM in Louisiana Wells generally less than 100 feet deep
2	Wells yield as much as 1,500 GPM Wells genfrally less than 500 feet deep
3	Wells yield from 50 to 500 GPM Wells generally range in depth from 500 to 2,500 feet in area B, from 100 to 1,500 feet in area C, and from 100 to 800 feet in area D.
4	Wells yield less than 50 GPM Wells generally less than 50 feet deep

DEPTH TO WATER BELOW LAND SURFACE IN PRINCIPAL AQUIFERS

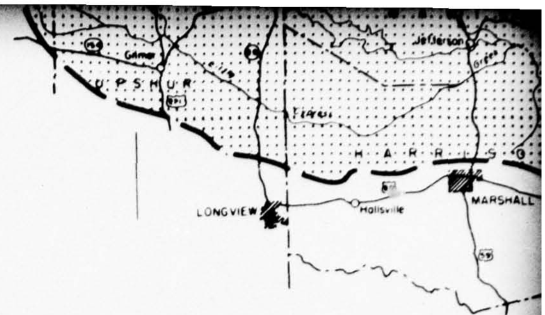
40-125 Between 40 and 125 feet

2


OKLAHOMA
ARKANSAS
MENA
POLK
<25
Broken Bow Reservoir
Gillham Reservoir
De Queen Reservoir
Dierks Reservoir
HOWARD
3-B
SEVIER
NASHVILLE
34°
<150
TY GROUP
<50
4-B
3-C
Millwood Reservoir
Foreman
LITTLE RIVER
Ashdown
TOKIO FORMATION AND NACATOCH SAND
HEMPSTEAD
HOPE
NEVADA
<120
ALLUVIUM
<50
4-C
WILCOX GROUP
CARRIZO SAND
MAGNOLIA
<100
WILCOX GROUP AND CARRIZO SAND
COLUMBIA
93°
ARKANASAS
LOUISIANA
33°
3-D
40-125
CLAIBORNE
Homer
<50
4-C
3-D
SPARTA SAND
AND
2
Jefferson
HARRISON
MARSHALL
Hallsville
SHREVEPORT
<100
40-125
<50
TEXAS
LOUISIANA
CANE RIVER FORMATION
32°
N

3

3



EXPLANATION

YIELD AND DEPTH OF WELLS

1 Well yields range from 500 GPM in Oklahoma and Texas to 1,700 GPM in Louisiana
Wells generally less than 100 feet deep

2 Wells yield as much as 1,500 GPM
Wells genfrally less than 500 feet deep

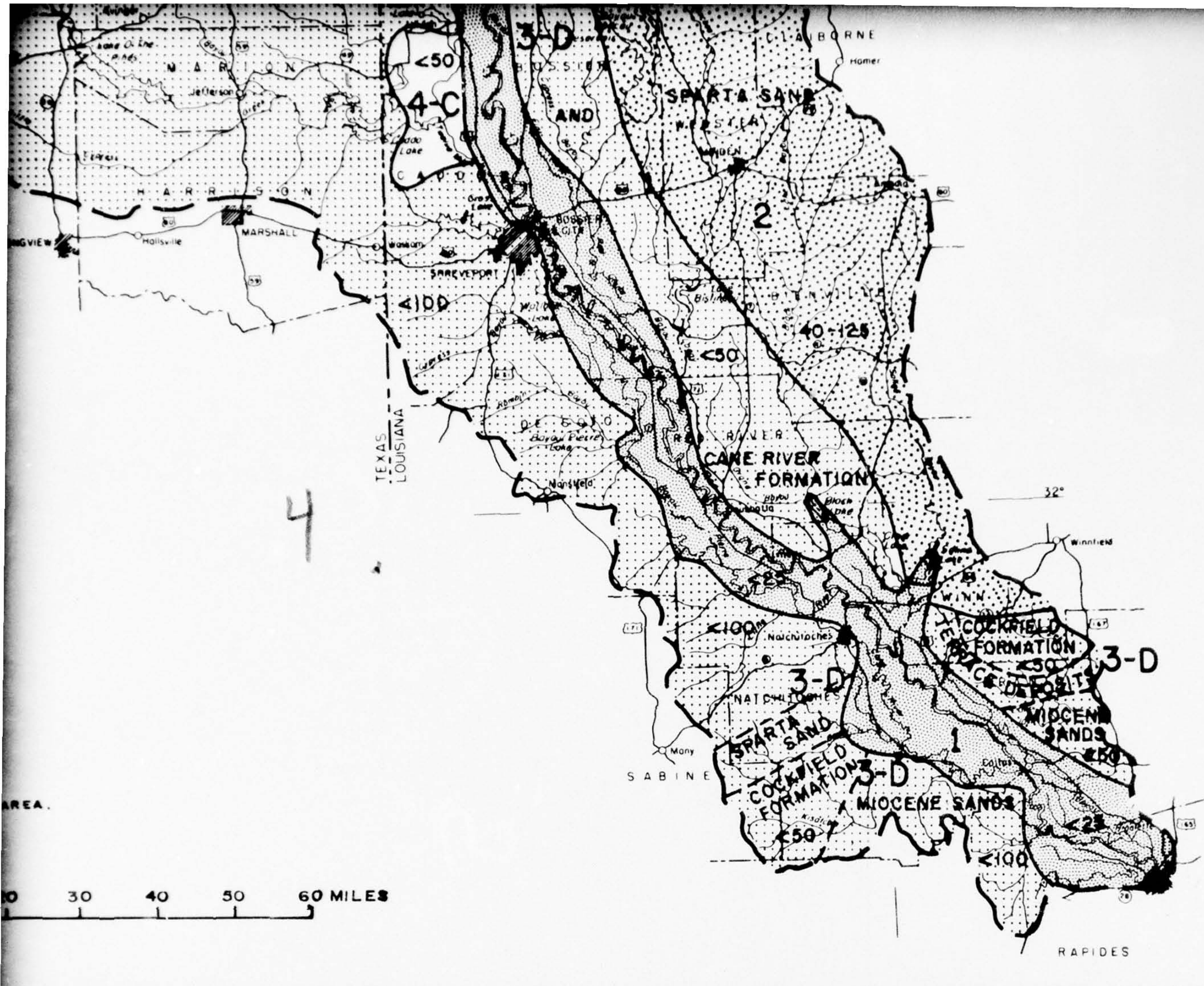
3 Wells yield from 50 to 500 GPM
Wells generally range in depth from 500 to 2,500 feet in area B, from 100 to 1,500 feet in area C, and from 100 to 800 feet in area D.

4 Wells yield less than 50 GPM
Wells generally less than 50 feet deep

DEPTH TO WATER BELOW LAND SURFACE IN PRINCIPAL AQUIFERS

40-125	Between 40 and 125 feet
<25	Less than 25 feet
	Line separating ground-water areas
	Red River basin boundary
	Line separating principal aquifers within ground-water areas
3-C	Number refers to ground water region and letter refers to ground water area.

0 10 20 30 40 50



RED RIVER BELO
ARK., LA., OKL
COMPREHENSIVE

AREAL EXTENT
GROUND WATER R
TO WATER, AND Y

JUNE 1968

5

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS

COMPREHENSIVE BASIN STUDY

AREAL EXTENT OF PRINCIPAL GROUND WATER RESERVOIRS, DEPTH TO WATER, AND YIELD OF WELLS

JUNE 1968 FILE NO. H-2-24396

FIGURE 4

Ground water from the Arbuckle Group is hard (greater than 120 p.p.m. hardness as $CaCO_3$), high in calcium and magnesium, and low in sodium. The dissolved-solids content generally is less than 500 p.p.m.

Area B. The Trinity Group and Woodbine Formation of Cretaceous age are the principal sources of ground water in the area. Locally, the Blossom Sand is an important aquifer. Fresh water occurs in these formations in the areas shown in figure 4.

The Trinity Group (the lowermost aquifer in the area) is exposed in a band 5 to 15 miles wide along the northern margin of the area. Elsewhere in the area, it lies in the subsurface at depths ranging from 500 feet near Durant and Hugo, Okla., to about 2,200 feet below ground surface in southeastern Fannin County, Tex.

The Woodbine Formation, of importance in the western part of area 3-B, lies several hundred feet above the Trinity Group and outcrops within the study area in a band 5 to 10 miles wide, generally parallel and contiguous to the Red River from Choctaw County westward. In southeastern Fannin and western Lamar Counties, Tex., at the southern extent of fresh water in the formation, the top of the Woodbine is about 1,200 feet below land surface. The average thickness of the formation is about 400 feet.

Yields as high as 500 g.p.m. may be expected from properly constructed wells in the Woodbine Formation. Static water levels in wells that tap the aquifer range from near land surface in the outcrop area, to about 300 feet below land surface in the deepest part of the aquifer. Near areas of heavy pumpage, such as at Sherman and Bonham, Tex., water levels have declined to about 400 feet below land surface and are at or below the top of the aquifer. However, in places along the outcrop, some wells have flowed since the turn of the century, indicating that water levels in the outcrop area have remained high and have not been seriously affected by the large withdrawals downdip.

The Woodbine Formation is not a significant source of ground water east of Choctaw County, Okla., because of the small percentage of sand in the formation.

Ground water in the Woodbine Formation generally is suitable for public supply. The concentration of iron in the water from the outcrop area generally exceeds the recommended limit of 0.3 p.p.m., but decreases downdip. Most of the water in the aquifer is soft (less than 60 p.p.m. hardness as $CaCO_3$). Mineralization increases with depth, and much of the water downdip has a dissolved-solids content in excess of 500 p.p.m.

The Blossom Sand of Austin age lies above the Trinity Group and the Woodbine Formation, and is an alternate source of water at moderate depth in central Fannin, Lamar, and Red River Counties, Tex. The fresh-water part of the aquifer is restricted principally to the outcrop area.

Ground water in the Blossom Sand contains high concentrations of sodium bicarbonate and dissolved solids, and is soft. The dissolved-solids and chloride contents generally exceed the recommended limits for drinking water.

With the exception of wells in the outcrop areas of the Trinity Group, Woodbine Formation, or Blossom Sand, domestic and stock supplies from other formations in area 3-B are obtained from shallow dug or drilled wells, generally less than 50 feet deep. Most of these wells yield less than 50 g.p.m.

Area C. The Nacatoch Sand of the Navarro Group is the principal source of ground water in parts of Hunt, Delta, Hopkins, Franklin, Lamar, Red River, and Bowie Counties, Tex., and in Little River and Hempstead Counties, Ark. The Tokio Formation is also a source of water to wells in Little River and Hempstead Counties, Ark. Yields as high as 500 g.p.m. may be expected in places from the Nacatoch Sand, and as high as 300 g.p.m. from the Tokio Formation. The thickness of the Nacatoch ranges from about 350 feet in parts of Delta and Hunt Counties, to about 500 feet in western Bowie County. Downdip, at the southern extent of the fresh water in southwestern Bowie County and Helpstead County, the depth to the top of the Nacatoch Sand is about 800 feet. The southern extent of the fresh water in the Nacatoch Sand and Tokio Formation terminates at the southern boundary of the area. In Texas the fresh-salt-water interface is marked by the Luling-Mexia-Talco Fault system, which coincides with the Sulphur and South Sulphur Rivers from Morris County westward. South of the fault system, the water is highly mineralized.

The depth to water in the area generally is less than 50 feet below ground surface.

Ground water from the Nacatoch Sand in Texas is highly alkaline, high in sodium bicarbonate, and is soft. In most places, the dissolved-solids content is less than 1,000 p.p.m., and the iron content normally is less than 0.3 p.p.m. This water is chemically suitable for municipal and many types of industrial uses. However, as a source of water for irrigation its use is restricted, because of the high sodium and salinity hazard, to areas where the soil is well drained and sandy.

In Arkansas the Nacatoch Sand and Tokio Formation contain water that is soft or moderately hard (less than 120 p.p.m. as $CaCO_3$), has a low chloride, low dissolved solids, and generally a low iron content. It is chemically suitable for most uses.

Area D. In this area moderate supplies of good-quality water are available from units of Tertiary and Quaternary age. The important, or potentially important, aquifers in the area are, in ascending order, the Wilcox Group, the Carrizo Sand, the Cane River Formation and its equivalents in Texas, Sparta Sand, Cockfield Formation, sands of Miocene age, and terrace deposits. The depths of wells in the area range from less than 100 feet, where the aquifers are thin, to about 800 feet in the thicker parts of the aquifer -- in parts of Cass, Morris, Camp, Upshur, and Wood Counties, Tex., and along the Arkansas-Louisiana state line. In southwestern Natchitoches Parish, fresh ground water is available as much as 2,000 feet below land surface in the Cockfield Formation. Wells that tap the units of Tertiary and Quaternary age of area D yield from a few gallons per minute to about 500 g.p.m. Well yields are relatively small owing to the fine-grained texture and lenticularity of the water-bearing sands. The present utilization of ground water is primarily for domestic and stock use.

Ground water in formations of Tertiary age occurs under artesian conditions, except in outcrop areas where water-table conditions exist. In most places static water levels are less than 100 feet below land surface, and in many places are less than 50 feet below the surface.

Ground water in the area generally is a sodium bicarbonate type; most of it is soft or only moderately hard. Concentrations of iron in excess of 0.3 p.p.m. may be expected in some places, principally on or near the outcrop. However, concentrations of most mineral constituents are within the limits set by the U. S. Public Health Service for drinking water. Ground water in the area is suitable for municipal and many industrial uses, but generally is unsuitable for irrigation. However, because of the relatively high rainfall, the sandy soil, and the topographic relief, most of the water probably could be used for supplementary irrigation without adverse effect to crops.

Region 4.

Area A. Relatively small yields are to be expected from wells that tap the formations of Paleozoic age in this area of southeastern Oklahoma and southwestern Arkansas. Most wells in the area yield less than 50 g.p.m., and those that yield more than 10 g.p.m. continuously for a week are considered good producers.

Most wells in the area are less than 100 feet deep, but larger yields are obtained from wells 100 to more than 600 feet in depth. Static water levels generally are less than 25 feet below land surface. Seasonal water-level fluctuations in wells generally are less than 10 feet, but larger fluctuations are common in dry years.

Ground water in area A is primarily of a calcium and sodium bicarbonate type, and the dissolved-solids content generally does not exceed 500 p.p.m. It is chemically suitable for most domestic and farm uses. In some places, however, ground water is high in calcium and magnesium hardness and contains one or more mineral constituents such as iron, chloride, nitrate, or dissolved solids in excess of recommended concentrations.

Area B. Terrace deposits of Quaternary age are the most important source of ground water in this area, which includes parts of McCurtain County, Okla., and Little River County, Ark. These deposits yield water to wells from sand and gravel 30 to 90 feet below land surface. Wells generally yield less than 50 g.p.m., although yields of as high as 150 g.p.m. have been recorded in places in Little River County.

In most places, ground water from the terrace deposits is very hard (more than 180 p.p.m.). Chloride content increases with depth. Chloride contamination probably is caused by the upward migration of mineralized water from the underlying saline-water-bearing formations.

Area C. In these areas, which are located in Caddo Parish, Louisiana, and in the Sulphur River Basin in Texas, ground water in sufficient quantities for domestic and stock use can be obtained in most places from shallow dug or drilled wells in local alluvial deposits and in near-surface formations. Most wells are less than 50 feet deep and yield less than 50 g.p.m.

b. Well spacing. Where two or more nearby wells are pumped, the mutual interference caused by lowering of the water table or the piezometric surface around each well may significantly reduce the capacities of the wells. The total drawdown at a given point caused by pumping several wells is equal to the sum of the drawdowns produced individually by the wells. It is important, therefore, that, wherever possible, wells be spaced far enough apart so as to minimize the effect of one pumping well on another.

The magnitude of drawdown caused by a pumping well is a function of the hydraulic characteristics of the aquifer. Commonly, these characteristics are determined by analyses of pumping tests. By pumping a well at a constant known rate and by measuring the drawdown of water levels in observation wells, the capacity of the aquifer to transmit (transmissibility) and store (storage capacity) water can be computed.

Individual values, and in some cases, the range of values of transmissibility of the principal aquifers in the lower Red River Basin, are given in table 7. Values of storage capacity are not shown in the table, but storage coefficients of 0.1 and 0.001 are used in figure 5 to represent water table and artesian conditions, respectively.

The data in table 7 may be used in conjunction with figure 5 to predict the effects of pumping at distances as great as 1 mile from the pumped well. As a rule, the distance-drawdown curve [Fig. 5(b)] for artesian conditions should be used when estimating the drawdown from pumping wells more than 100 feet in depth. Water in wells that tap the Red River alluvium in Arkansas and Louisiana generally occurs under artesian conditions.

The information shown in figure 5 is based upon a pumping rate of 300 g.p.m. for a period of 400 days. Assuming that the aquifer is not dewatered, drawdowns for other pumping rates are directly proportional to that shown. For example, doubling the yield of the well would double the drawdown.

c. Estimated potential aquifer yield. The aquifers that underlie the lower Red River Basin can provide substantially more water than is being used. Within the basin, large areas of unexplored or underdeveloped ground-water resources are available to meet the increased needs of future development. The aquifers in the basin can provide an estimated 800 m.g.d. of fresh water. Figure 6 shows, by subbasins, the quantities of water available. The availability estimates given in this appendix are based entirely on aquifer characteristics and do not consider the economic factors involved in developing these quantities. These quantities have been derived from calculated and assumed values of potential unit yield applied to the productive areas, which are shown shaded in figure 4, and are based on utilization of ground water that is lost to streams.

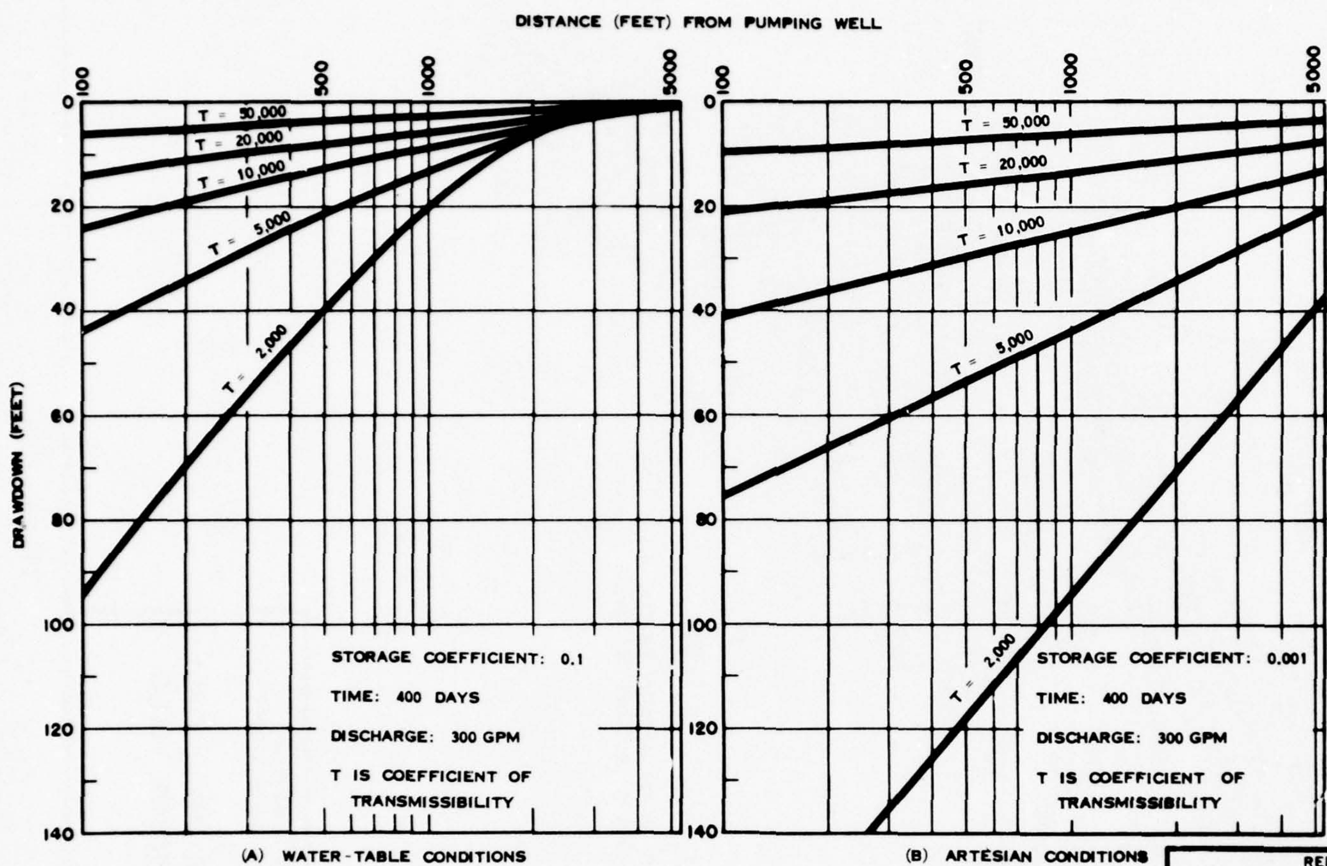
In most places in the basin, withdrawals of ground water from wells represent only a small percentage of the total amount of water perennially available from the aquifers. Natural discharge in the form of seepage to streams, both within and outside the basin, and evapotranspiration, in places where the water table is near the land surface, account for the major part of the ground-water loss. With proper distribution of, and pumpage from, wells throughout the aquifers, present natural discharges could be diverted for use at points of need. Proper well distribution and pumpage depend upon the hydraulic characteristics of the aquifers. Withdrawals of water to the extent indicated in figure 6 could be maintained indefinitely, but, if the water is used consumptively, may result in significant reduction of base flows in the tributary streams.

TABLE 7

TRANSMISSIBILITIES OF BASIN AQUIFERS

Aquifer	Transmissibility (gpd per foot)	Location of test(s)
Trinity Group	300-4,700 14,000	Grayson County, Tex. McCurtain County, Okla.
Woodbine Formation	1,400-12,500	Grayson County, Tex.
Blossom Sand	3,800	Red River County, Tex.
Tokio Formation	4,500	Hempstead County, Ark.
Nacatoch Sand	2,200 3,600	Bowie County, Tex. Hempstead County, Ark.
Wilcox Group	[a]1,000-14,000 4,200 4,700 4,700	Sulphur River and Cypress Creek Basins, Tex. Natchitoches Parish, La. Bossier Parish, La. Webster Parish, La.
Carrizo Sand	12,000	Natchitoches Parish, La.
Cane River Formation	12,000	Bossier Parish, La.
Sparta Sand	12,000	Natchitoches Parish, La.
Cockfield Formation	12,000	Natchitoches Parish, La.
Miocene sands	1,400-60,000	Rapides Parish, La.
Terrace deposits	27,000	Bossier Parish, La.
Valley alluvium	41,000-100,000	Arkansas and Louisiana

[a]Values are for Carrizo and Wilcox (Cypress aquifer) in northeast Texas.



RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

RELATION OF DISTANCE TO DRAWDOWN AROUND A PUMPING WELL FOR (A) WATER-TABLE AND (B) ARTESIAN CONDITIONS

JUNE 1968 FILE NO. H-2-24396

FIGURE 5

FIGURE 5

EXPLANATION

45 Figures refer to potential aquifer yield in millions of gallons per day.

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

ESTIMATED POTENTIAL GROUND-WATER YIELD

JUNE 1968 FILE NO H-2-24396

FIGURE 6

18. SURFACE WATER

a. <u>Water-supply characteristics of streams.</u> The flow characteristics of a stream and the chemical and physical properties of the water are the bases for determining the extent to which a stream can be utilized for water supply. Of particular significance are the magnitude and quality of streamflow during low-flow periods. These characteristics vary with time, with location, and in some places are influenced by manmade changes, such as impoundment, clearing, enlarging, or realigning of the channel.

In this report low-flow characteristics are described in terms of magnitude and frequency of occurrence and percentage of time of occurrence. The minimum mean-discharge rate for 30 consecutive days which will occur on the average of once every 2 years, and the daily discharge that was exceeded 90 percent of the time are used to demonstrate streamflow characteristics. Figure 7 shows selected values of low-flow frequency and flow duration for locations where streamflow data have been collected. These data are expressed in cubic feet per second. However, in the following discussion, discharge for the 30-day 2-year low flow, hereinafter referred to as the low-flow index, is expressed in cubic feet per second per square mile to eliminate the effect of size of drainage area and thus show the effects of basin geology.

The principal tributaries to the Red River from the west include Sulphur River, Cypress Creek, Bayou Pierre, and Cane River.

The gaging station on the main stem of the Sulphur River near Talco, Tex. (3432), and those stations on the North Sulphur River and South Sulphur River near Cooper, Tex. (3430 and 3425), have low-flow indices of zero. Upstream from Talco, the Sulphur River and its tributaries from the north are underlain by the Navarro Group and the Taylor Marl of Late Cretaceous age. Both of these units have a low porosity and low permeability. White Oak Creek near Talco (3435), which has a low-flow index of 0.001 c.f.s. per square mile, flows through the outcrop of the Midway Group of Paleocene age almost parallel to and a few miles south of South Sulphur River.

Cypress Creek flows across the outcrop of the Wilcox Formation and Claiborne Group, and is in an area of slightly higher base flow than that of the Sulphur River. In the Cypress Creek Basin, the low-flow indices range from no flow for small tributaries to 0.008 c.f.s. per square mile for Cypress Creek near Jefferson, Tex. (3460). The index increase of 0.002 c.f.s. per square mile on the main stem of Cypress Creek between Pittsburg and Jefferson is probably due to yield from the Claiborne Group.

The differences between the low-flow indices in the lower part of the Sulphur River and Cypress Creek Basins, and those in the upper

part of the Sulphur River Basin may be attributed largely to the depth to which the streams are incised, the depth of the water table below land surface, and to the porosity and permeability of the formations in the immediate area. Bayou Pierre, a western tributary to the Red River in Louisiana, has two gaged tributaries, Boggy Bayou (3510) and Cypress Bayou (3515). These streams, both of which have low-flow indices of zero, traverse the outcrop of the Midway Group. Rambin Bayou (3516.7), which also has a low-flow index of zero, lies mostly in terraces of Quaternary age. Bayou Na Bonchasse near Mansfield, La. (3517), has a low-flow index of 0.05 c.f.s. per square mile. This stream is incised into the Wilcox Group, and thus has the higher index. Buffalo Bayou near Naborton, La. (3517.2), and Bayou Terre Blanc near Allen, La. (3517.6), are incised into the Naborton Formation of the Wilcox Group and have low-flow indices of 0.002 c.f.s. per square mile and 0.001 c.f.s. per square mile, respectively. Two streams that lie in the more highly productive Catahoula Formation of Miocene age are Little Sandy Creek near Kisatchie, La. (3540), and Hemphill Creek near Hotwells, La. (3550). The low-flow indices for these streams are 0.06 c.f.s. per square mile and 0.42 c.f.s. per square mile, respectively.

The eastern tributaries to the Red River in Arkansas and northern Louisiana are in an area of relatively low yield. Most of the streams in the upper Loggy Bayou Basin have low-flow indices of zero, because they are not cut deeply enough into the underlying formations to intercept the ground-water levels. Further south, however, the low-flow indices for Bayou Dorcheat and Bodcau Bayou indicate a measurable ground-water inflow. Bayou Dorcheat near Minden, La. (3490), and Bodcau Bayou near Sarepta, La. (3495), have low-flow indices of 0.002 and 0.001 c.f.s. per square mile, respectively. These streams are incised into terrace deposits and into the outcrop of the Cook Mountain Formation, and have some contact with the Quaternary alluvium. The Quaternary alluvium presumably is the source of the base-flow yield. Brushy Creek near Sibley, La. (3491), and Loggy Bayou near Ninock, La. (3500), have low-flow indices of 0.02 and 0.01 c.f.s. per square mile, respectively. Brushy Creek above the station near Sibley is in contact with the Quaternary alluvium and with the Sparta Sand; whereas, the lower reaches of Loggy Bayou are in contact only with the alluvium.

The low-flow indices of streams in the Saline Bayou Basin range from 0 to 0.21 c.f.s. per square mile. Streams that derive their base flow from the Sparta Sand have indices of 0.08 c.f.s. per square mile or higher. These streams and their respective low-flow indices are: Saline Bayou near Lucky, La. (3520), 0.08 c.f.s. per square mile; Saline Bayou near Goldonna, La. (3521), 0.11 c.f.s. per square mile; Kepler Creek near Sparta, La. (3524), 0.21 c.f.s. per square mile; and Castor Creek at Castor, La. (3527), 0.18 c.f.s. per square mile. Black Lake Bayou at Minden, La. (3522), has a low-flow index of 0.006 c.f.s. per square mile; whereas, at the downstream gaging

station near Castor (3525), the low-flow index is 0.04 c.f.s. per square mile. The increase in yield is derived from high-yielding tributaries in the Sparta Sand. The lower part of the Saline Bayou Basin is in the alluvium and the low-flow index near Clarence, La. (3530), is 0.01 c.f.s. per square mile. The decrease in unit yield between Goldonna and Clarence is attributed to the low-yielding tributary area and to large evapotranspiration losses in the intervening chain of shallow lakes. Two tributaries in the low-yielding area between Goldonna and Clarence are Black Lake Creek near Gibsland, La. (3523), which is incised into the Cook Mountain Formation and has a low-flow index of 0.002 c.f.s. per square mile, and Grand Bayou near Coushatta, La. (3528), which is in terrace deposits and has a low-flow index of zero.

Flows on the main stem of Red River below Denison Dam are affected by regulation; therefore, low-flow characteristics have not been determined.

Variability of flow of the Red River can be illustrated by considering the gaging station at Index, Ark. For the 28-year period of record, from 1936 to 1964, the maximum flow in the Red River was 297,000 c.f.s. on 23 February 1938 and the minimum flow was 378 c.f.s. on 28 November 1956. The average flow from the contributing area above the Index station for the same period of record was 12,180 c.f.s. (0.289 c.f.s. per square mile).

Notable differences exist in the amount of unit runoff from the Red River Basin as the river enters the more humid climate in Arkansas and Louisiana. Long-term discharge records show that the average flow of the Red River at Denison Dam is 5,058 c.f.s. (0.15 c.f.s. per square mile) and that the average flow of the Red River between Denison and Shreveport, La., is 19,992 c.f.s. (0.96 c.f.s. per square mile), or better than a sixfold increase in unit yield. This increase in unit yield reflects the higher rate of runoff due to higher annual precipitation in the lower reaches of the river, as compared to the area above Denison Dam. Also, a factor affecting unit yields is the lower evaporative losses in the lower reaches of the basin.

Low-flow-frequency and flow-duration data for all daily-record gaging stations in the basin having as much as 5 years of record during the base period are presented in tables 8 and 9. The stations are listed in downstream order corresponding to the system used by the Geological Survey in surface-water reports. The base period for the data in these tables is the 29-year period, 1929-1957. Locations of the stations are shown on figure 7.

The low-flow-frequency data (table 8) can be used to estimate the probable future magnitude and frequency of low flows at the indicated locations, and to estimate the reservoir storage required in order to maintain a specified draft rate. (A detailed description of the method is given in Professional Paper 448-G, Speer, 1966, p. G27.)

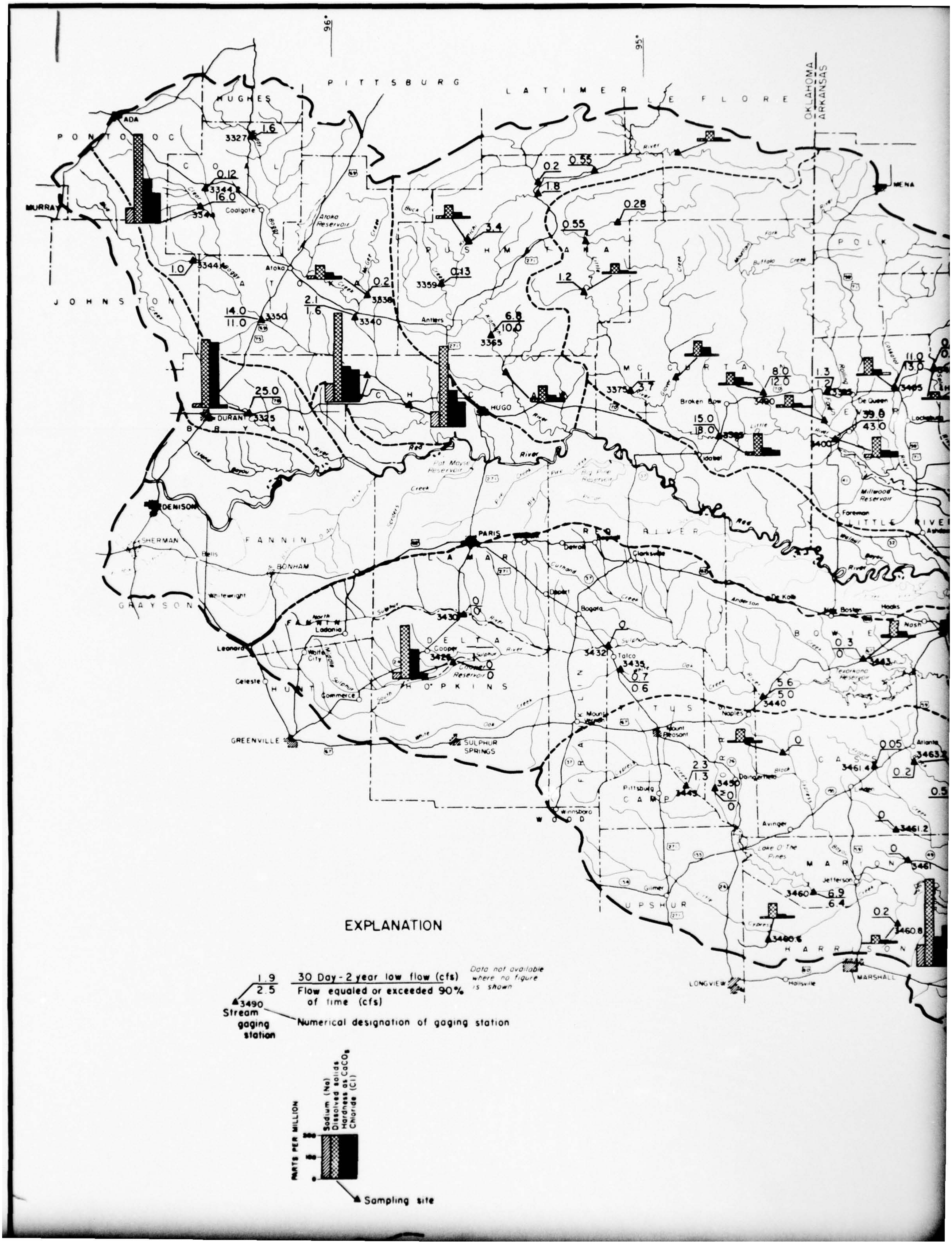
Flow-duration data (table 9) can be plotted on logarithmic-probability paper if a graphical presentation is desired. The slope of the duration curve is influenced by the hydrologic and geologic characteristics of the river basin upstream from the station. The slopes of the duration curves for streams that have large low-flow yields are flatter than those for streams that have small low-flow yields. Thus, the flow-duration data are useful for comparing the flow characteristics of different streams.

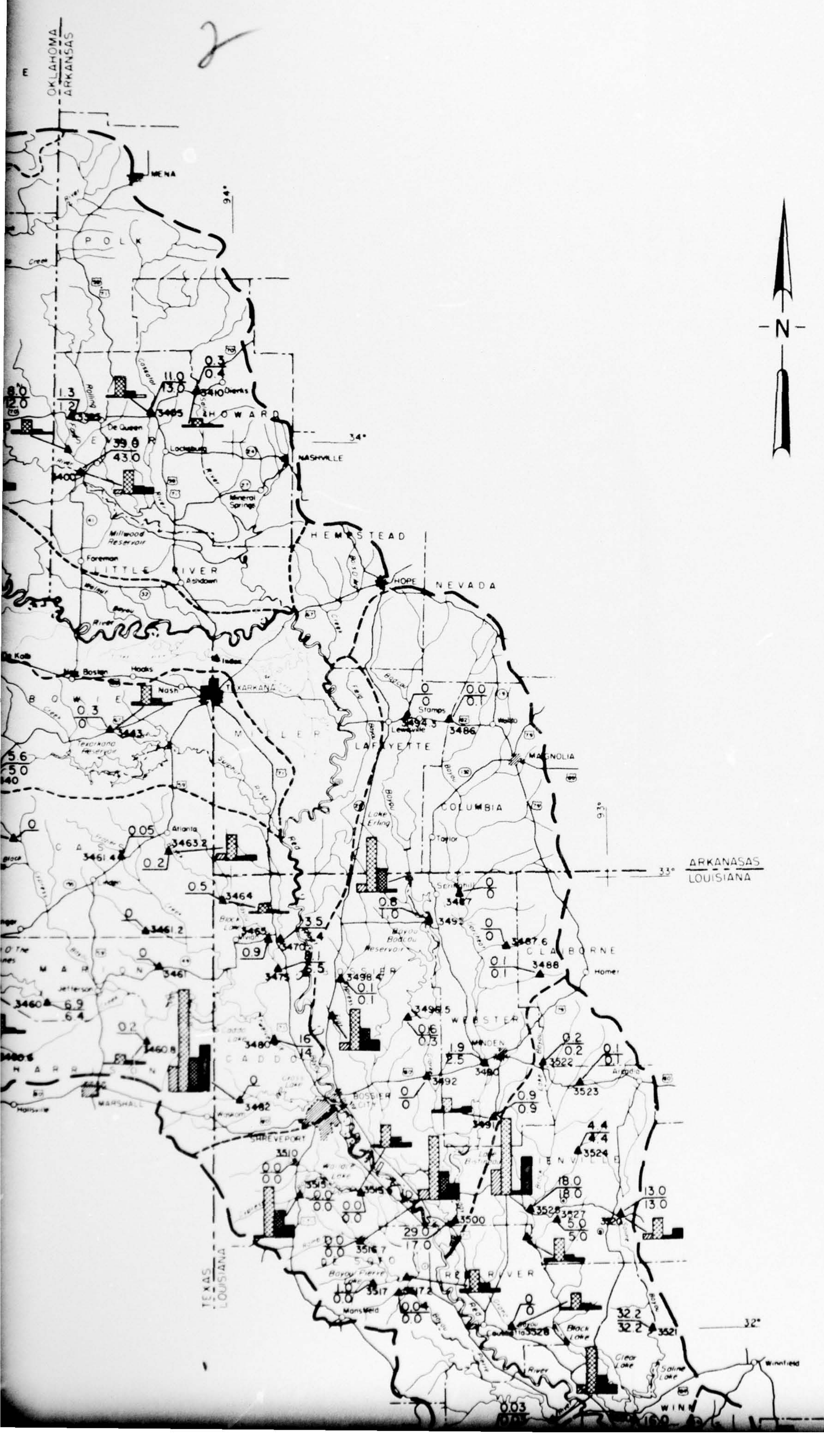
b. Quality of surface water. During low flow, the chemical quality of water in the streams in the lower Red River Basin is controlled largely by the composition of water from the geologic units in the drainage basin, except where altered by the addition of industrial and oilfield wastes. In streams where the composition of the geologic units is the principal factor controlling water quality, the type of water and the amount of dissolved solids depend primarily on the solubility of the aquifer materials and the length of time the water is in contact with these materials. In these streams, the dissolved-solids content generally is low, and the chemical characteristics of the water from each stream are fairly uniform. The dissolved-solids content of water in streams that receive oilfield wastes is variable, depending upon the rate of streamflow and the amount of waste.

Diagrams on figure 7 show the concentrations of sodium and chloride, hardness, and dissolved solids of the water in most of the streams during periods of low flow. Red River water is high in chloride, sulfate, and dissolved-solids content, and is moderately hard or hard. During a period of observation from 1955 to 1958, the dissolved-solids content of Red River water at Shreveport equaled or exceeded 500 p.p.m. nearly one-third of the time, and hardness equaled or exceeded 100 p.p.m. 77 percent of the time. With treatment, water from the Red River frequently is suitable for domestic use and for many industrial uses. Red River water can be used for irrigation only on crops that have a high salinity tolerance.

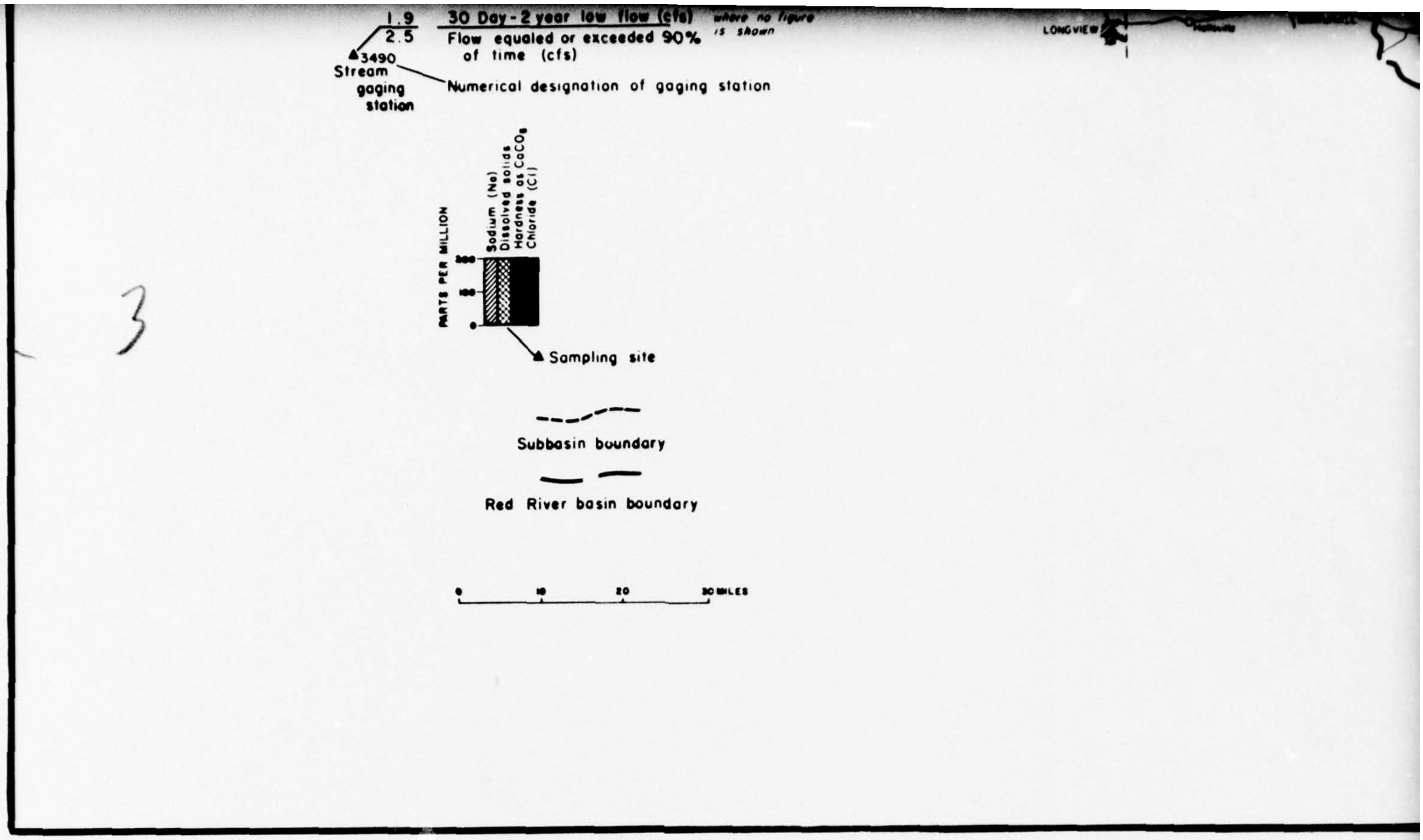
Water in the Kiamichi and Little Rivers is of excellent chemical quality, and is suitable for most uses with little or no treatment. Concentrations of most chemical constituents are low, even during periods of low streamflow. Water in the Blue and Muddy Boggy Rivers is classified as hard, or very hard. Hardness is probably due to the solution of calcium, magnesium, and bicarbonate from the limestone formations in the upper basins. The high chloride concentration in Muddy Boggy River probably is caused by seepage of brines from oilfields in Clear Boggy Creek Basin.

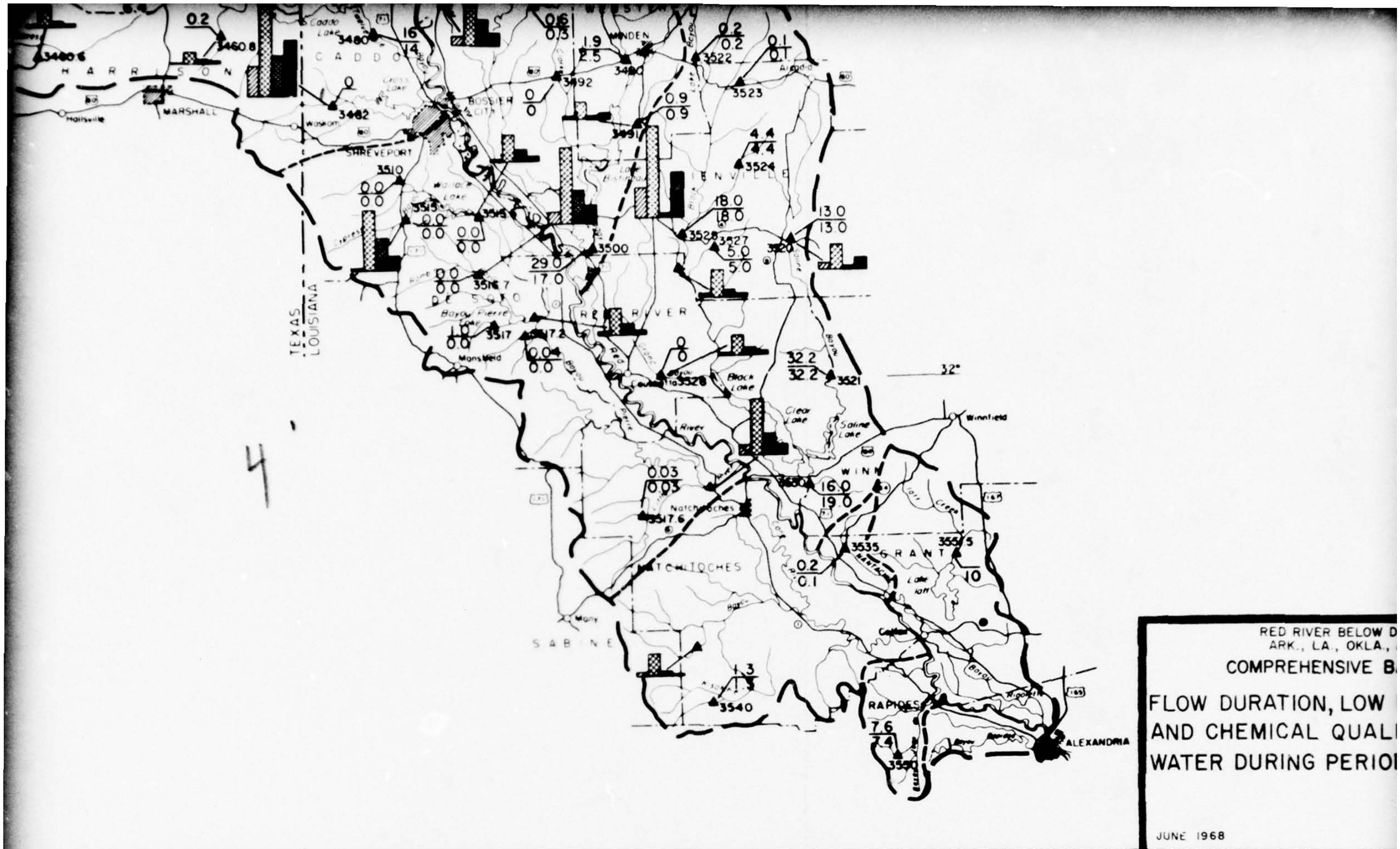
Chemical analyses of water in many of the small streams from Denison Dam to the mouth of the Sulphur River that drain directly into the Red River are not available. However, on the basis of analyses of low flows in adjacent basins, water in the north-bank


PITTSBURG
LATIMER
LE FLORE
OKLAHOMA
ARKANSAS
HUGHES
PONTOTOC
COAL
ATOKA
PUSHMATAHA
POLK
JOHNSTON
MC CURTAIN
CHOCTAW
BRYAN
SEVIER
FANNIN
LAMAR
RED RIVER
GRAYSON
DELTA
HOPKINS
HUNT
BOWIE
TITUS
FRANKLIN
CAMP
WOOD
CASS
MARION
UPSHUR
HARRISON
ADA
MURRAY
MENA
Coalgate
Atoka
Atoka Reservoir
Antlers
HUGO
DURANT
Broken Bow
Idabel
De Queen
Millwood Reservoir
Foreman
DENISON
SHERMAN
Bells
BONHAM
PARIS
Detroit
Clarksville
Whitewright
Ladonia
Leonard
Wolfe City
Celeste
Commerce
Cooper
Cooper Reservoir
GREENVILLE
SULPHUR SPRINGS
Deport
Bogata
Talco
De Kalb
New Boston
Hooks
Nash
Texarkana Reservoir
Naples
Mount Vernon
Mount Pleasant
Daingerfield
Pittsburg
Winnsboro
Avinger
Lake O' The Pines
Jefferson
Gilmer
LONGVIEW
Hallsville
MARSHALL
Atlanta
Pat Mayse Reservoir
Big Pine Reservoir
EXPLANATION
1.9
2.5
3490
30 Day - 2 year low flow (cfs)
Flow equaled or exceeded 90% of time (cfs)
Data not available where no figure is shown
Stream gaging station
Numerical designation of gaging station
PARTS PER MILLION
Sodium (Na)
Dissolved solids
Hardness as $CaCO_3$
Chloride (Cl)
Sampling site



2
OKLAHOMA
ARKANSAS
MENA
94°
POLK
HOWARD
De Queen
Lockesburg
NASHVILLE
34°
Mineral Springs
Millwood Reservoir
Foreman
LITTLE RIVER
Ashdown
HEMPSTEAD
HOPE
NEVADA
New Boston
Hooks
Nash
TEXARKANA
BOWIE
MILLER
Texarkana Reservoir
Stamps
Lewisville
LAFAYETTE
MAGNOLIA
COLUMBIA
93°
Lake Erling
Taylor
Atlanta
33°
ARKANASAS
LOUISIANA
CLAIBORNE
Homer
WEBSTER
Minden
CADDO
BOSSIER CITY
SHREVEPORT
MARION
Jefferson
HARRISON
MARSHALL
Hallsville
TEXAS
LOUISIANA
RED RIVER
Mansfield
Black Lake
Clear Lake
Saline Lake
32°
Winnfield
WINN
N


1.9
30 Day-2 year low flow (cfs) where no figure is shown
2.5
Flow equaled or exceeded 90% of time (cfs)
3490
Stream gaging station
Numerical designation of gaging station
PARTS PER MILLION
Sodium (Na)
Dissolved solids
Hardness as $CaCO_3$
Chloride (Cl)
200
100
0
Sampling site
Subbasin boundary
Red River basin boundary
0
10
20
30 MILES
LONGVIEW
3



HARRISON
MARSHALL
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SHREVEPORT
BOSSIER CITY
MINDEN
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NATCHITOCHES
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RAPIDES
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TEXAS
LOUISIANA
32°
RED RIVER BELOW D
ARK., LA., OKLA.,
COMPREHENSIVE B
FLOW DURATION, LOW
AND CHEMICAL QUAL
WATER DURING PERIO
JUNE 1968

5

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

FLOW DURATION, LOW FLOW FREQUENCY AND CHEMICAL QUALITY OF SURFACE WATER DURING PERIODS OF LOW FLOW

JUNE 1968 FILE NO. H-2-24396

FIGURE 7

TABLE 8

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOW AT DAILY-RECORD
GAGING STATIONS IN THE LOWER RED RIVER BASIN,
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS

Station	Station name	Drainage area (sq mi)	Period (consecutive days)	Annual low flow, in cubic feet per second, for indicated recurrence interval, in years				
				1.2	2	5	10	20
3340----	Muddy Boggy Creek near Farris, Okla--------	1,087	7	5.2	0.4	0	0	0
			14	8.0	.9	0	0	0
			30	17.5	2.1	0	0	0
			60	53	11.0	.3	0	0
			120	195	44.0	2.5	.3	0
3350----	Clear Boggy Creek near Caney, Okla---------	720	7	18.5	10	0	0	0
			14	21	11	0	0	0
			30	30	14	1.4	--------	---------
			60	48	19	2.9	--------	---------
			120	135	36	6.7	1.4	---------
3365----	Kiamichi River near Belzoni, Okla----------	1,423	7	14	3.0	0	--------	---------
			14	17	4.4	0	--------	---------
			30	36	6.7	0	--------	---------
			60	97	19	1.7	.2	---------
			120	360	85	19	8.0	3.4
3375----	Little River near Wright City, Okla--------	645	7	6.6	.3	0	0	0
			14	9.8	.5	0	0	0
			30	20.5	1.1	0	0	0
			60	49	3.4	.2	0	0
			120	200	21	4.6	3.0	2.0
3385----	Little River near Idabel, Okla-------------	1,226	7	29	7.4	1.3	.4	---------
			14	38	10	2.0	.7	---------
			30	64	15	3.4	1.6	---------
			60	125	28	5.9	3.1	---------
			120	325	78	21	14	9.5
3390----	Mountain Fork near Eagletown, Okla---------	787	7	25	3.3	0	0	0
			14	33	4.8	0	0	0
			30	57	8.0	0	0	0
			60	114	18	1.7	0	0
			120	345	91	18	6.2	2.6
3395----	Rolling Fork near DeQueen, Ark-------------	181	7	3.9	.4	.1	0	0
			15	5.7	.6	.1	0	0
			30	11	1.3	.1	.1	0
			60	23	3.6	.3	.1	.1
			120	80	16	3.0	.8	.3
			183	162	65	16	8.6	4.8
3400----	Little River near Horatio, Ark-------------	2,674	7	71	18	5.0	2.7	1.6
			15	100	24	6.0	3.2	1.8
			30	170	39	9.1	4.5	2.5
			60	315	67	15	7.3	3.8
			120	1,140	295	61	32	16
			183	2,300	1,080	320	190	122
3405----	Cossatot River near DeQueen, Ark-----------	361	7	19	7.0	2.9	1.8	1.2
			15	25	9.1	3.6	2.2	1.5
			30	39	11	4.6	3.0	2.1
			60	68	17	6.9	4.6	3.2
			120	200	49	15	9.2	6.6
			183	370	155	46	25	16
3410----	Saline River at Dierks, Ark----------------	124	7	2.0	.1	0	0	0
			15	3.9	.2	0	0	0
			30	6.8	.3	0	0	0
			60	14	1.4	.1	0	0
			120	48	9.4	.9	.2	.1
			183	103	40	10	3.5	1.1
3425----	South Sulphur River near Cooper, Tex-------	527	7	0	0	0	0	0
			15	.1	0	0	0	0
			30	.6	0	0	0	0
			60	4.2	0	0	0	0
			120	62	3.4	0	0	0
			183	170	44	12	6.0	3.2
3430----	North Sulphur River near Cooper, Tex-------	276	7	0	0	0	0	0
			15	.1	0	0	0	0
			30	1.1	0	0	0	0
			60	5.0	.5	.1	0	0
			120	26	3.5	.5	.2	.1
			183	90	26	3.9	1.8	1.0

TABLE 8 (cont'd)

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOW AT DAILY-RECORD GAGING STATIONS IN THE LOWER RED RIVER BASIN, ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS

Station	Station name	Drainage area (sq mi)	Period (consecutive days)	Annual low flow, in cubic feet per second, for indicated recurrence interval, in years				
				1.2	2	5	10	20
3435-----	Whiteoak Creek near Talco, Tex-------------	494	7	0.8	0.4	0.1	0	0
			15	1.0	.5	.2	.1	0
			30	3.1	.7	.2	.1	0
			60	15	1.9	.4	.1	0
			120	83	15	1.4	.4	.2
			183	210	55	14	4.5	1.3
3440-----	Sulphur River near Darden, Tex-------------	2,774	7	8.9	1.7	.1	0	0
			15	12	2.4	.2	0	0
			30	31	5.6	.4	0	0
			60	85	19	1.2	.1	0
			120	380	86	16	1.9	.2
			183	1,080	284	83	39	16
3445-----	Cypress Creek near Pittsburg, Tex----------	366	7	6.5	.7	0	0	0
			15	8.4	1.1	0	0	0
			30	13	2.3	0	0	0
			60	21	5.1	.2	0	0
			120	48	13	3.0	.4	0
			183	128	32	9.5	4.9	2.2
3450-----	Boggy Creek near Daingerfield, Tex---------	72	7	.1	0	0	0	0
			15	.2	0	0	0	0
			30	.6	0	0	0	0
			60	2.4	0	0	0	0
			120	7.0	.6	0	0	0
			183	23	4.4	.3	0	0
3460-----	Cypress Creek near Jefferson, Tex----------	850	7	16	4.2	.7	.1	0
			15	20	5.2	.9	.2	0
			30	30	6.9	1.3	.3	0
			60	49	12	2.5	.8	.1
			120	108	30	7.8	3.3	1.3
			183	280	76	22	12	6.8
3470-----	Kelly Bayou near Hosston, La---------------	116	7	4.6	2.7	2.0	1.8	1.6
			15	5.2	3.0	2.2	2.0	1.8
			30	6.3	3.5	2.5	2.2	2.0
			60	9.2	4.8	3.1	2.8	2.5
			120	17	7.8	4.6	3.9	3.4
			183	34	14	7.3	5.6	4.8
3475-----	Black Bayou near Gilliam, La---------------	364	7	12	5.8	3.7	3.2	2.9
			15	14	6.6	4.2	3.6	3.2
			30	18	8.1	4.9	4.2	3.7
			60	29	11	5.9	4.8	4.2
			120	54	17	7.8	5.9	4.9
			183	112	34	12	8.4	4.9
3480-----	Twelvemile Bayou near Dixie, La------------	3,137	7	25	11	6.6	5.5	4.6
			15	32	13	7.4	6.2	5.2
			30	52	16	8.5	6.8	5.7
			60	129	26	11	7.9	6.6
			120	345	62	17	11	8.8
			183	900	201	44	22	14
3490-----	Bayou Dorcheat near Minden, La-------------	1,097	7	8.8	1.1	.2	.1	0
			15	11	1.3	.2	.1	0
			30	15	1.9	.3	.1	0
			60	32	4.0	.5	.2	.1
			120	104	15	2.1	.7	.3
			183	275	61	12	4.6	2.1
3495-----	Bodcau Bayou near Sarepta, La--------------	546	7	1.8	.4	.2	.1	.1
			15	2.5	.5	.2	.2	.1
			30	4.4	.8	.3	.2	.2
			60	13	2.0	.6	.4	.3
			120	52	6.9	1.6	1.0	.8
			183	172	36	6.3	3.1	2.0
3496.5---	Bodcau Bayou near Shreveport, La-----------	683	7	4.0	.2	0	0	0
			15	5.7	.3	0	0	0
			30	8.4	.6	0	0	0
			60	20	1.6	0	0	0
			120	64	8.8	.7	.1	0
			183	178	42	6.9	2.0	.6
3500-----	Loggy Bayou near Ninoch, La----------------	2,628	7	58	18	5.2	2.5	1.4
			15	70	22	6.1	2.9	1.6
			30	99	29	7.8	3.6	2.0
			60	173	44	11	5.1	2.8
			120	400	100	23	11	6.0
			183	950	263	71	38	24

TABLE 8 (cont'd)

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOW AT DAILY-RECORD GAGING STATIONS IN THE LOWER RED RIVER BASIN, ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS

Station	Station name	Drainage area (sq mi)	Period (consecutive days)	Annual low flow, in cubic feet per second, for indicated recurrence interval, in years				
				1.2	2	5	10	20
3510----	Boggy Bayou near Keithville, La------------	79	7	0.1	0	0	0	0
			15	.1	0	0	0	0
			30	.4	0	0	0	0
			60	.8	.1	0	0	0
			120	3.1	.3	0	0	0
			183	10	1.7	.3	.1	.1
3515----	Cypress Bayou near Keithville, La----------	66	7	.1	0	0	0	0
			15	.1	0	0	0	0
			30	.2	0	0	0	0
			60	.8	0	0	0	0
			120	3.3	.2	0	0	0
			183	14	1.9	.2	0	0
3515.5--	Cypress Bayou near Shreveport, La----------	266	7	.2	0	0	0	0
			15	.4	0	0	0	0
			30	.8	0	0	0	0
			60	3.3	.1	0	0	0
			120	20	.8	0	0	0
			183	68	8.3	.3	0	0
3520----	Saline Bayou near Lucky, La----------------	154	7	18	11	6.8	5.4	4.3
			15	20	12	7.2	5.8	4.6
			30	21	13	7.9	6.2	5.0
			60	27	16	9.3	7.1	5.7
			120	44	22	13	9.7	7.8
			183	68	33	20	16	13
3525----	Black Lake Bayou near Castor, La-----------	423	7	27	15	8.8	6.8	5.4
			15	30	16	9.6	7.3	5.8
			30	34	18	10	8.0	6.4
			60	48	22	12	9.3	7.2
			120	98	39	18	13	10
			183	184	70	31	22	17
3530----	Saline Bayou near Clarence, La-------------	1,386	7	40	6.8	.8	.2	.1
			15	60	10	1.3	.3	.1
			30	90	16	1.9	.5	.1
			60	162	32	4.5	1.2	.4
			120	360	95	19	6.6	2.4
			183	730	270	79	37	19
3540----	Little Sandy Creek at Kisatchie, La--------	21.4	7	1.9	1.1	.7	.6	--------
			15	2.1	1.2	.8	.6	--------
			30	2.4	1.3	.9	.7	--------
			60	3.7	1.8	1.0	.8	--------
			120	6.8	3.1	1.8	1.4	--------
			183	15	6.5	3.6	2.8	--------
3550----	Hemphill Creek near Hot Wells, La----------	18	7	8.8	7.2	6.4	5.8	5.4
			15	9.1	7.4	6.4	6.0	5.6
			30	9.5	7.6	6.6	6.2	5.8
			60	11	8.4	7.0	6.4	6.0
			120	13	9.9	7.8	7.2	6.6
			183	16	12	9.9	8.8	7.8

TABLE 9

DURATION OF DAILY FLOW AT DAILY-RECORD
GAGING STATIONS IN THE LOWER RED RIVER BASIN

Station	Station name	Drainage area (sq mi)	Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of time								
			99	95	90	80	60	40	20	5	1
3340-----	Muddy Boggy Creek near Farris, Okla---	1,087	0	0.3	1.6	8.4	38	120	580	5,300	14,500
3350-----	Clear Boggy Creek near Caney, Okla----	720	0	5.4	11	19	45	105	320	2,600	7,800
3365----	Kiamichi River near Belzoni, Okla-----	1,423	0	1.5	10	44	200	580	1,800	8,200	25,500
3375----	Little River near Wright City, Okla---	645	0	.8	4.0	24	120	360	1,000	4,100	13,000
3385----	Little River Near Idabel, Okla--------	1,226	1.2	7.2	18	55	235	670	2,000	8,200	19,000
3390----	Mountain For, near Eagletown, Okla----	787	0	2.2	12	46	220	570	1,500	5,500	17,000
3395----	Rolling Fork near DeQueen, Ark--------	181	0	.4	1.2	4.7	28	100	295	1,320	4,200
3400----	Little River near Horatio, Ark--------	2,674	4.3	16	43	130	540	1,680	4,800	18,000	39,500
3405----	Cossatot River near DeQueen, Ark------	361	3.2	8.0	13	27	87	237	655	2,400	8,000
3410----	Saline River near Dierks, Ark---------	124	.1	.2	.4	3.1	21	69	225	790	2,550
3425----	South Sulphur River near Cooper, Tex--	527	0	0	0	.1	1.4	11	90	1,460	6,950
3430----	North Sulphur River near Cooper, Tex--	276	0	0	0	.2	1.8	9.6	45	465	5,800
3435----	Whiteoak Creek near Talco, Tex--------	494	.1	.3	.6	2.2	14	92	740	3,650	7,600
3440----	Sulphur River near Darden, Tex--------	2,774	0	1.1	5.0	19	112	570	2,950	12,200	28,000
3445----	Cypress Creek near Pittsburg, Tex-----	366	0	.1	1.3	7.3	29	84	245	1,060	4,300
3450----	Boggy Creek near Daingerfield, Tex----	72	0	0	0	.1	3.2	18	56	232	1,140
3460----	Cypress Creek near Jefferson, Tex-----	850	.1	2.4	6.4	21	95	336	920	2,700	7,000
3470----	Kelly Bayou near Hosston, La----------	116	1.9	2.7	3.4	5.3	13	44	146	471	1,120
3475----	Black Bayou near Gilliam, La----------	364	4.0	5.2	6.5	11	48	213	600	1,560	3,220
3480----	Twelvemile Bayou near Dixie, La-------	3,137	7.2	10	14	29	385	2,020	5,050	11,500	20,400
3490----	Bayou Dorcheat near Minden, La--------	1,097	0	.7	2.5	8.4	96	630	1,790	5,250	10,900
3495----	Bodcau Bayou near Sarepta, La---------	546	.3	.6	1.0	2.9	38	330	970	2,610	5,270
3496.5--	Bodcau Bayou near Shreveport, La------	683	0	.1	.3	3.1	88	585	1,470		
3500----	Loggy Bayou near Ninoch, La-----------	2,628	2.9	9.8	17	40	275	1,900	4,140	9,200	16,500
3510----	Boggy Bayou near Keithville, La-------	79	0	0	0	.2	1.7	9.4	48	355	1,500
3515----	Cypress Bayou near Keithville, La-----	66	0	0	0	.1	1.3	6.6	32	295	1,820
3515.5--	Cypress Bayou near Shreveport, La-----	266	0	0	0	0	8.5	123	510	1,150	1,700
3520----	Saline Bayou near Lucky, La-----------	154	6.7	10	13	18	38	86	221	715	1,690
3525----	Black Lake Bayou near Castor, La------	423	9.2	14	18	26	84	360	810	2,210	4,750
3530----	Saline Bayou near Clarence, La--------	1,386	1.7	9.6	19	48	380	1,450	2.720	5,050	7,500
3540----	Little Sandy Creek at Kisatchie, La---	21.4	0	0	0	1.4	3.2	7.5	21	98	340
3550----	Hemphill Creek near Hot Wells, La-----	18	6.0	6.8	7.4	8.4	11	14	21	89	381

tributaries probably is soft; whereas, water in the south-bank tributaries is hard, or very hard. Water in Walnut Bayou is very hard, and the dissolved-solids content ranges from 500 to 1,000 p.p.m. Chemical analyses of water in Barkman Creek and McKinney Bayou show it to be soft and low in dissolved solids.

The dissolved-solids content of water in the Sulphur River and Cypress Creek Basins averages less than 500 p.p.m., and the chloride concentrations do not exceed 250 p.p.m., except in streams such as Paw Paw Bayou, where oilfield brines have caused locally high concentrations. Water in the upper reaches of Sulphur River is hard during low flow periods. Hardness probably is due to the solution of calcium and magnesium bicarbonate from the chalk and marl formations which underlie the upper basins.

Water in Bayou Pierre and Cane River has low concentrations of dissolved solids, chlorides, and sulfates, and is soft. At most times, the water needs treatment to remove color and iron.

The chloride content of water in Loggy Bayou during low flow ranges from 28 to 375 p.p.m. and hardness ranges from 39 to 352 p.p.m. Analyses of water from Bodcau Bayou show large variations in dissolved solids (59 to 1,130 p.p.m.), chloride (4 to 655 p.p.m.), and hardness (18 to 245 p.p.m.). These variations are not indicative of the natural quality of the streams, but probably are due to oilfield or other industrial pollution. Water in Black Lake Bayou near Castor is of good quality and is chemically suitable for most uses without treatment. During low-flow periods in Saline Bayou, the water is hard and generally contains concentrations of chloride in excess of the recommended limits for drinking water.

19. INTRODUCTION

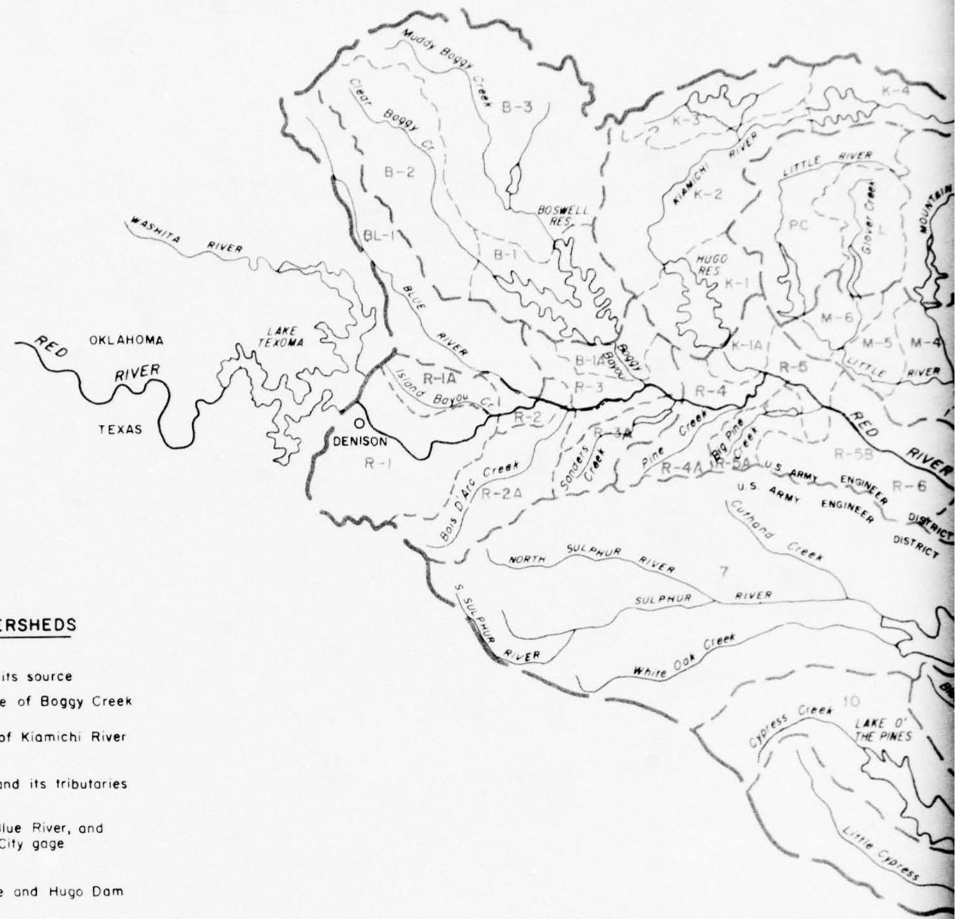
The material contained in this chapter was developed primarily for the "Interim Report on Navigation and Bank Stabilization," and is in general included as tentative material in appendix I, "Hydrology and Hydraulic Design" to that report. Subsequent study has confirmed its validity and it is presented herein for ease of reference.

20. FLOOD HYDROGRAPH ANALYSES AND COMPUTATIONS

a. General. To analyze in detail the influence of the proposed improvements in modifying flood magnitudes and frequencies at the site of project features, it was necessary to develop flood hydrographs at many locations where discharge stations were not available. The drainage basin above Fulton, Arkansas, was divided into 37 subareas, and that below Fulton into 22 subareas, to establish the contributing areas for computing flood hydrographs from both storms of record and modified storms. The locations of the areas and streams are shown on figure 8.

b. Unit hydrographs. Derivation of unit hydrographs involves analysis of observed data to determine the time of occurrence and areal distribution of precipitation, the determination of losses and rainfall excesses, and the separation of flow components into runoff and base flow. Unit hydrographs were derived for the 59 basin subareas based on Snyder's method, as described in the Corps of Engineers EM-1110-2-1405, "Flood Hydrograph Analyses and Computations." Unit hydrograph coefficients were determined from records of 21 stream gaging stations located on various tributaries within the basin having drainage areas varying in size from 124 to 2,754 square miles. Coefficients and basin characteristics from observed hydrographs are listed in table 10. The synthetic unit hydrographs for ungaged areas were derived from these coefficients by taking into account the differences in drainage area and basin characteristics. Pertinent data relating to synthetic unit hydrograph determination and base flows and infiltration indexes for each area are shown in table 11. Tabulations of the 6-hour unit-hydrograph discharges are shown in tables 12 and 13.

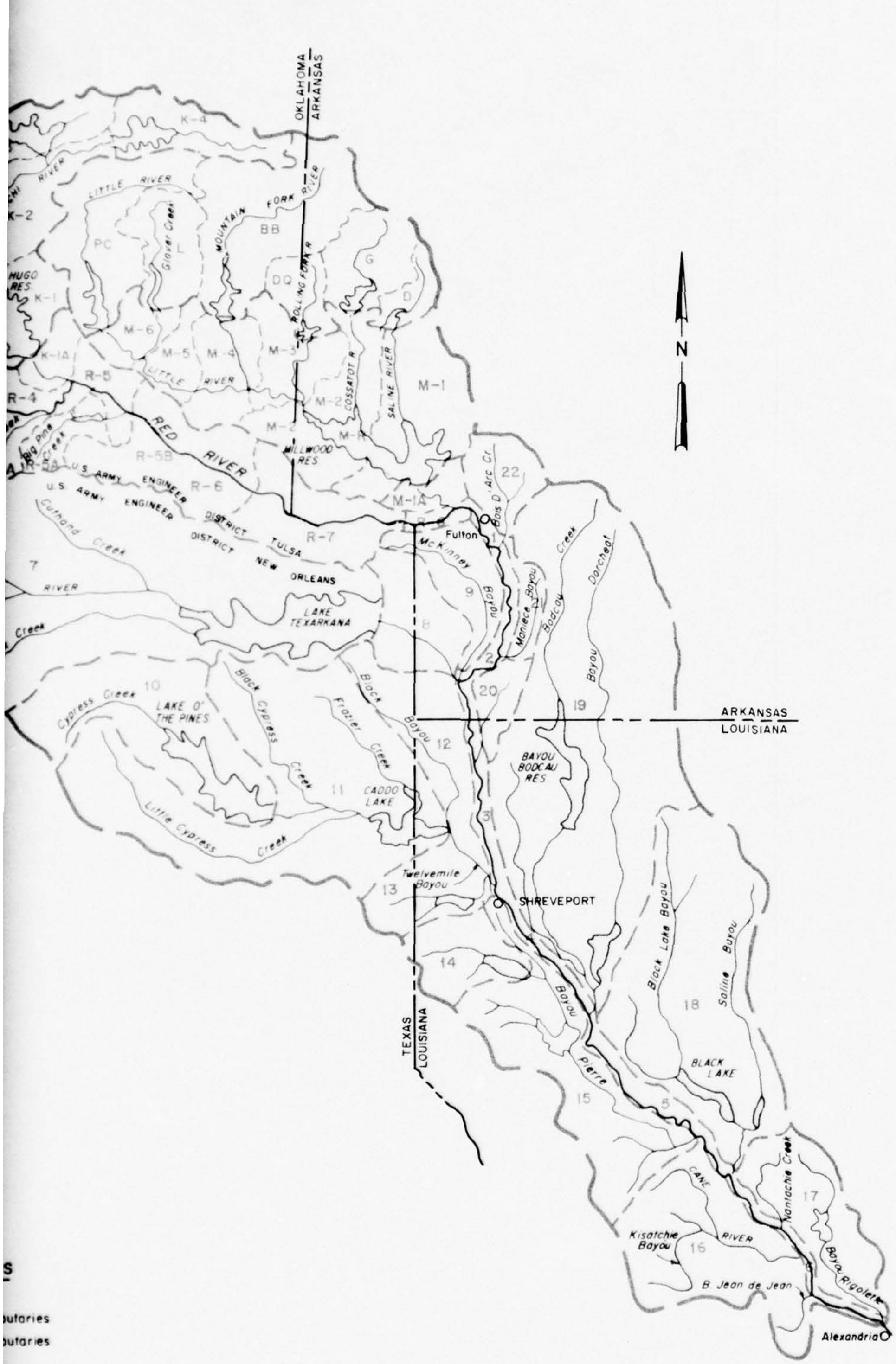
c. Computed hydrographs. Inflow hydrographs for synthetic floods and for each major actual flood series since 1938 were computed for each subbasin area, utilizing unit hydrographs, daily rainfall amounts, infiltration rates, and base flows.

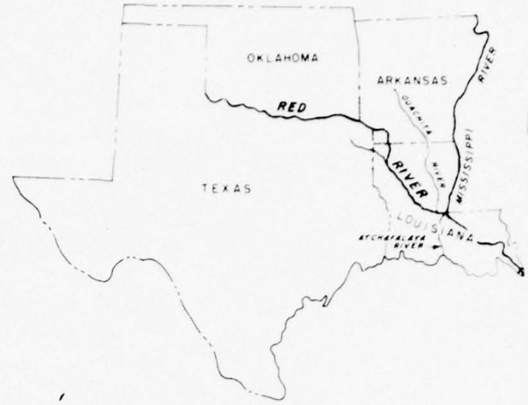


AREA NO.	DESCRIPTION OF WATERSHEDS
BL-1	Above mouth of Blue River to its source
B-3, B-2, B-1	Above Boswell Dam to the source of Boggy Creek
K-3, K-4 K-2, K-1	Above Hugo Dam to the source of Kiamichi River
PC, L, BB DQ, G, D	Above reservoirs on Little River and its tributaries
R-1A, R-2, R-3 B-1A, R-1, R-2A R-3A	Red River below Denison Dam, Blue River, and Boswell Dam and above Arthur City gage
K-1A, R-4, R-5 R-4A, R-5A, R-5B R-6, R-7	Red River below Arthur City gage and Hugo Dam and above Index gage
M-6, M-5, M-4 M-3, M-2, M-R M-1	Above Millwood Dam and below upstream reservoirs on Little River and tributaries
M-1A, R-8	Below Index gage, Millwood Dam and above Fulton gage
1	Red River below Fulton to Garland City reach
2	Red River Garland City to Spring Bank reach
3	Red River Spring Bank to Shreveport reach
4	Red River Shreveport to Coushatta reach
5	Red River Coushatta to Grand Ecore reach
6	Red River Grand Ecore to Alexandria reach
7	Above Texarkana Dam
8	Below Texarkana Dam to mouth of Sulphur River
9	Above mouth of McKinney Bayou
10	Above Ferrells Bridge Dam
11	Below Ferrells Bridge Dam to Caddo Lake Dam
12	Above mouth of Twelvemile Bayou
13	Above mouth of Cross Bayou
14	Above Wallace Lake Dam
15	Above mouth of Bayou Pierre
16	Watersheds of Cane River and Bayou Jean de Jean and their tributaries
17	Watersheds of Nantachie Creek and Bayou Rigolette and their tributaries

AREA NO.	DESCRIPTION OF WATERSHEDS
18	Above mouth of Saline Bayou and its tributaries
19	Above mouth of Loggy Bayou and its tributaries
20	Above mouth of Posten Bayou
21	Above mouth of Maniece Bayou
22	Above mouth of Bois D'Arc Creek

2-1





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RED RIVER BELOW DENISON DAM
LA., ARK., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
NAVIGATION AND BANK STABILIZATION

WATERSHED DIVISIONS
DENISON DAM TO ALEXANDRIA, LA.

SCALE OF MILES
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JUNE 1968

FILE NO. H-2-24396

FIGURE

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TABLE 10

OBSERVED UNIT HYDROGRAPH DATA

Location	Storm period	Area (sq.mi.)	L	L_{ca}	Duration	t_{PR} (hrs.)	t_p (hrs.)	C_p	C_t	Initial loss (inches)	F_{av} (in./hr.)
Red River, from Denison Dam to Fulton, Ark.											
Saline Creek @ Dierks Gage	May 4- 8, 1961	124	34.5	16.8	2	8.0	7.9	.93	1.2	1.10	0.05
	Apr 30-May 2, 1956					7.5	7.3	1.17	1.2	1.40	0.05
Mt. Fork River @ Eagle Town Gage	Feb 12-14, 1950	787	86.4	46.0	2	16.0	16.2	.86	1.4	0.91	0.03
	Jan 23-28, 1949					17.0	17.3	.97	1.4	0.75	0.03
Rolling Fork River @ DeQueen, Ark. Gage	May 11-14, 1953	181	32	17.1	2	8.0	7.9	.85	1.2	0.84	0.12
	Sep 16-18, 1950					8.0	7.9	.53	1.2	0.25	0.05
Cossatot River @ DeQueen, Ark. Gage	Sep 20-23, 1950	361	50	30.0	2	9.0	8.9	.76	1.0	1.60	0.18
	Jan 24-27, 1949					12.0	12.0	.75	1.3	1.02	0.05
Little River @ Wright City Gage	Jan 24-29, 1949	645	68.4	30.0	2	8.0	7.8	.45	.8	1.55	0.01
	Sep 14-18, 1950					8.5	8.4	.50	.8	0.46	0.05
Kiamichi River @ Belzoni Gage	Jun 16-17, 1945	1,420	124.3	50.1	2	18.0	18.3	.41	2.6	0.73	0.02
	Apr 30-May 1,1949					17.0	16.5	.45	2.5	1.33	0.05
Blue River @ Blue Gage	Apr 23-28, 1942	478	81.5	32.5	6	39.0	39.3	.90	3.7	0.52	0.05
	Nov 26-30, 1962					24.0	23.6	.70	2.2	0.92	0.05
Muddy Boggy @ Farris Gage	Apr 28-29, 1940	1,120	73	45.0	6	24.0	23.6	.44	2.1	1.07	0.02
	Jun 5-6, 1943					18.0	17.3	.35	1.5	1.51	0.03
Clear Boggy @ Caney Gage	Feb 8-9, 1944	732	52	22.0	6	27.0	26.7	.70	3.2	0.15	0.05
	Jun 5-6, 1943					18.0	17.3	.64	2.1	0.79	0.06
Red River, from Fulton, Ark. to Alexandria, La.											
Cypress Creek near Benton, Ark.	Apr 26-29, 1957	133	20	10	6	36	33	0.6	7.3	0.37	0.024
	Apr 25-28, 1958					40	48	0.5	8.2	0.26	0.023
McKinney Bayou at Kemps Br., Ark.	Jan 11-14, 1950	309	42	18	6	33	33	0.3	4.5	0.03	0.001
	Dec 5-10, 1960					42	43	0.4	5.9	0.35	0.045
Bayou Pierre near Lake End, La.	Sep 16-22, 1958	473	62	33	6	135	140	0.8	14.3	0.50	0.067
	Dec 5- 8, 1960					69	71	0.4	7.2	0.23	0.028
*Caddo Lake near Mooringsport, La.	Jan 10-13, 1950	1,894	92	52	6	288	301	0.7	23.9	0.25	0.015
	Sep 13-17, 1950					279	291	0.7	23.1	0.30	0.078
Saline Bayou near Clarence, La.	Apr 17-21, 1959	1,386	113	59	6	132	120	0.4	9.4	0.25	0.010
Wallace Lake Reservoir near Shreveport, La.	Apr 28-29, 1953	266	37	16	6	33	33	0.7	4.9	0.26	0.090
	Aug 2- 3, 1955					45	46	1.0	6.8	0.25	0.090
Bayou Dorcheat near Minden, La.	Apr 29-May 2,1950	1,097	90	47	6	69	71	0.7	5.8	0.23	0.023
	Apr 25-May 1,1958					69	71	1.1	5.8	0.23	0.022
Bayou Bodcau Reservoir near Shreveport, La.	Apr 25-May 3, 1958	683	85	45	6	69	70	0.6	5.9	0.06	0.027
Black Lake Bayou near Castor, La.	Apr 30-May 4,1944	423	49	29	6	69	71	0.5	8.1	0.23	0.020
	Apr 5, 1956					87	90	0.7	10.2	0.23	0.055
Saline Bayou near Lucky, La.	Mar 30-Apr 1,1945	154	39	13	6	27	27	0.6	4.2	0.25	0.59
	Apr 5, 1956					27	27	0.7	4.2	0.25	0.59
Sulphur River near Darden, Tex.	Apr 29-30, 1941	2,754	163	100	6	98	75	1.0	5.3	0.00	0.020
Cypress Creek at Ferrells Bridge near Jefferson, Tex.	Apr 6- 8, 1942	850	80	42	6	92	89	1.0	8.1	1.00	0.050

*Excludes influence of Cypress Creek at Ferrells Bridge near Jefferson, Texas, a tributary area of 850 square miles.

Definition of Symbols:

L - Total length of longest watercourse

L_{ca} - Distance along the main drainage channel from gage to computed centroid of drainage area.

t_{pR} - Interval in hours from center of mass (centroid) of rainfall excess to the time of observed discharge

t_p - Interval in hours from midpoint of unit rainfall duration, t_r to time of peak unit hydrograph corresponding to specified "t_r"

C_p - Coefficient, $C_p = \dfrac{t_p q_p}{640}$

C_t - Coefficient, $C_t = \dfrac{t_p}{(LL_{ca})^{0.3}}$

F_{av} - Infiltration rate

TABLE 11

SYNTHETIC UNIT HYDROGRAPH DATA

Subarea	Area sq. mi.	L	L_{ca}	t_{pR}	t_p	C_p	C_t	q_p (c.f.s./ sq. mi.)	Base flow (c.f.s.)	F_{av} (in./hr.)
Red River, from Denison Dam to Fulton, Arkansas										
R-1	621	44	20	12.0	11.0	0.60	1.45	34.9	550	0.02
R-1A	148	31	18	17.0	16.2	0.63	2.40	24.9	550	0.02
R-2	110	12	6	7.0	5.8	0.75	1.60	82.8	550	0.02
R-2A	416	60	27	19.0	18.3	0.66	2.00	23.1	195	0.03
R-3	222	30	15	7.0	5.8	0.45	0.93	49.7	550	0.02
R-3A	190	34	19	13.0	12.0	0.66	1.74	35.2	195	0.03
R-4	88	16	8	7.0	5.8	0.68	1.35	75.1	550	0.02
R-4A	195	34	17	13.0	12.0	0.73	1.78	38.9	195	0.03
R-5	124	14	7	6.0	4.7	0.61	1.19	83.1	550	0.02
R-5A	95	19.7	10	9.5	8.4	0.64	1.84	43.2	100	0.03
R-5B	75	14.8	8	9.0	8.0	0.66	2.15	46.7	95	0.03
R-6	517	44	22	21.0	20.4	0.63	2.58	19.8	550	0.02
R-7	515	62	31	18.0	17.3	0.55	1.78	20.4	550	0.02
R-8	206	22	11	12.0	11.0	0.73	2.12	42.4	550	0.02
K-1A	121	18.5	9.5	9.5	8.4	0.63	1.79	47.0	310	0.02
K-1	312	32	19	15.5	14.7	0.52	2.14	22.6	310	0.02
K-2	775	55	25	19.0	18.6	0.58	2.14	19.9	310	0.02
K-3	275	28	11	10.0	9.0	0.56	1.62	39.8	310	0.02
K-4	347	45	20	13.0	12.6	0.43	1.64	21.8	310	0.02
B-1A	156	30	13	7.3	6.0	0.60	1.00	64.0	365	0.02
B-1	466	42	19	10.0	8.9	0.60	1.20	43.2	365	0.02
M-1	492	40	20	5.0	3.7	0.42	0.50	72.6	1240	0.06
M-2	445	33	10	8.0	6.8	0.57	1.19	53.6	1240	0.06
M-3	265	32	18	17.0	16.0	0.60	2.40	24.0	1240	0.06
M-4	260	18	7	6.5	5.2	0.59	1.22	72.6	1240	0.06
M-5	145	27	13	6.0	5.0	0.44	0.82	56.4	1240	0.06
M-6	155	18	12	6.5	5.2	0.71	1.04	87.4	1240	0.06
L	291	40	20	10.0	8.9	0.85	1.20	61.1	1240	0.06
Red River, from Fulton, Arkansas, to Alexandria, Louisiana										
1	30	-	-	9	-	-	-	55.93	0	0.023
2	47	-	-	9	-	-	-	55.92	0	0.025
3	74	-	-	9	-	-	-	55.92	0	0.025
4	100	-	-	9	-	-	-	55.92	0	0.019
5	75	-	-	9	-	-	-	55.92	0	0.029
6	94	-	-	9	-	-	-	55.92	0	0.034
7	3400	163	100	63	64	0.8	3.5	7.24	1500	0.062
8	348	45	28	34	34	0.8	4.0	14.70	500	0.062
9	360	53	27	45	46	0.3	5.2	4.61	100	0.023
10	850	80	42	44	45	1.0	4.5	17.55	700	0.044
11	1894	92	52	284	296	0.7	23.5	1.65	200	0.047
12	519	84	47	69	71	0.6	5.9	5.40	100	0.027
13	259	28	14	136	141	0.7	23.5	3.30	50	0.047
14	266	37	16	39	40	0.8	5.8	13.30	100	0.090
15	872	85	39	118	122	0.6	10.8	3.10	100	0.048
16	856	90	43	56	57	0.6	4.8	7.15	200	0.116
17	499	65	31	87	90	0.6	9.2	4.65	50	0.038
18	1386	113	59	123	127	0.4	9.1	1.89	50	0.010
19	2649	145	76	148	153	0.7	9.3	3.09	100	0.024
20	114	20	12	31	31	0.6	5.9	12.00	10	0.027
21	118	26	12	29	29	0.3	5.2	7.12	10	0.023
22	220	30	19	35	35	0.3	5.2	5.90	50	0.023

Definition of symbols:

L - Total length of longest watercourse.

L_{ca} - Distance along main drainage channel from gage to computed centroid of drainage area.

t_{pR} - Interval in hours from center of mass (centroid) of rainfall excess to the time of observed discharge.

t_p - Interval in hours from midpoint of unit rainfall duration Tr to time of peak unit hydrograph corresponding to specified "t_r."

C_t - Coefficient, $C_t = \frac{t_p}{(LL_{ca})^{0.3}}$

C_p - Coefficient, $C_p = \frac{t_p \; q_p}{640}$

q_p - Peak value of unit hydrograph per square mile

F_{av} - Infiltration rate.

TABLE 12

6-HOUR UNIT HYDROGRAPH IN 24-HOUR INCREMENTS
FOR DRAINAGE AREAS 200 SQ. MI. OR GREATER

Area No.	R-1	R-2A	R-3	R-6	R-7	R-8	K-1	B-1	B-2	B-3	BL-1	M-1	M-2	M-3	M-4	P_c	L	BB	K-2	K-3	K-4	G
Area (sq.mi.)	621	416	222	577	515	206	312	466	720	1087	676	492	445	265	260	635	291	754	775	275	347	271
Red River, from Denison Dam to Fulton, Ark.																						
Days																						
1	9800	8800	2400	11000	9000	3800	6000	4800	8100	8800	6000	3000	4000	5000	1500	8800	3100	21000	15000	4500	5800	2600
2	1100	2400	600	3500	3200	400	1500	400	3800	4000	10400	100	0	500	200	500	300	600	5000	200	1700	100
3	0	800	200	1200	1500	0	200	0	2700	2600	2200	0		0	0	0	0		500	0	200	0
4		0	0	400	500		0		700	800	600								0		0	
5				0	100				0	200	0											
6					0					0												

Area No.	7(A)	8	9	10(A)	11	12	13	14	15	16	17	18	19	22	7(B)	10(B)
Area (sq.mi.)	3400	348	360	850	1894	519	259	266	872	856	499	1405	2607	220	3400	850
Red River, from Fulton, Ark. to Alexandria, La.																
Days																
1	11600	3837	1300	11800	305	1080	65	1650	400	2070	926	650	625	1220	880	810
2	20200	3000	1660	6240	655	2180	180	3505	925	5495	1912	1425	1680	1270	2180	3185
3	20800	1350	1600	1530	1050	2800	430	1775	1900	5620	2230	2020	2980	985	3900	7290
4	12700	520	1360	460	1450	2190	690	280	2625	4040	2040	2420	4700	750	6800	6150
5	8100	160	1020	120	1810	1520	840	0	2703	2910	1520	2650	6410	530	12000	2500
6	4600	0	760	0	2130	1040	854		2680	1860	1136	2600	7875	340	12380	1515
7	2400		580		2420	720	835		2600	900	890	2520	7985	215	11700	1000
8	1000		450		2650	560	755		2350	10	708	2400	7050	140	9860	620
9	200		340		2850	430	655		1890	0	560	2300	4355	95	8000	335
10	0		250		2990	350	550		1460		436	2160	3380	65	6380	185
11			170		3090	280	440		1190		328	2020	2860	45	5000	65
12			100		3128	210	315		950		236	1900	2470	30	3870	0
13			40		3085	145	200		725		164	1760	2155	14	2960	
14			5		3020	90	110		510		108	1610	1890	0	2220	
15			0		2870	40	35		310		64	1470	1675		1540	
16					2665	0	0		125		30	1320	1525		970	
17					2465				0		16	1160	1365		560	
18					2225						0	1010	1230		300	
19					1995							860	1100		120	
20					1760							700	985		5	
21					1515							550	885		0	
22					1255							400	775			
23					1020							210	675			
24					810							50	590			
25					605							0	500			
26					400								415			
27					195								345			
28					33								275			
29					0								225			
30													175			
31													125			
32													90			
33													60			
34													35			
35													28			
36													23			
37													18			
38													13			
39													8			
40													3			
41													0			

(A) With improvements.
(B) Under natural conditions.

TABLE 13

6-HOUR UNIT HYDROGRAPH
(DRAINAGE AREAS OF 200 SQ. MI. OR LESS)
DISCHARGES IN C.F.S.

Area No.	B-1A	R-1A	R-2	R-3A	R-4	R-4A	R-5	R-5A	R-5B	K-1A	D	D_9	M-5	M-6	M-R	
Area (sq.mi.)	156	148	110	190	88	195	124	95	75	121	113	169	145	155	149	
Red River, from Denison Dam to Fulton, Ark.																
Time (hr.)																
6	5400	700	4000	1500	2000	1400	3000	370	290	1900	1830	4390	5280	6380		16030
12	8000	1700	5300	5600	4100	4800	6700	2930	2290	5100	7170	9440	3370	7100		
18	3100	3150	1600	5800	1600	6200	2400	3510	2790	3450	1960	2180	1440	1870		
24	900	2950	100	3800	500	4100	500	1910	1480	1400	630	880	1840	760		
30	250	2300	0	2000	150	2400	100	840	660	500	290	510	1660	330		
36	50	1700		900	40	1200	30	350	270	240	130	330	1030	150		
42	0	1200		400	0	400	0	200	150	80	70	190	500	70		
48		750		250		250		80	90	0	20	110	230	20		
54		500		110		150		40	60		0	50	140	0		
60		350		50		50						0	80			
66		200		20		0							30			
72		90		0									0			
78		0														

Area No.	1	2	3	4	5	6	20	21
Area (sq.mi.)	30	47	74	100	75	94	114	118
Red River, from Fulton, Ark. to Alexandria, La.								
Time (hr.)								
6	516	807	1273	1720	1290	1617	200	80
12	1678	2628	4138	5592	4194	5256	420	200
18	774	1213	1910	2582	1936	2426	684	600
24	258	404	637	860	645	809	1026	830
30	0	0	0	0	0	0	1368	840
36							1300	835
42							1170	830
48							1026	815
54							900	780
60							780	715
66							684	630
72							590	560
78							485	510
84							385	470
90							315	435
96							265	405
102							220	375
108							175	345
114							140	315
120							100	285
126							65	260
132							35	230
138							0	210
144								185
150								165
156								145
162								125
168								105
174								90
180								70
186								60
192								45
198								35
204								25
210								15
216								10
222								0

21. DERIVATION OF DESIGN FLOOD

a. General. A number of floods of various magnitudes were derived for the main stem of the Red River below Fulton, Arkansas, under the conditions anticipated with the planned improvements in the interest of navigation and bank stabilization in place. These floods were used to evaluate the economics of levee work required to provide protection against floods with return frequencies up to once in 150 years. These analyses demonstrate that protection for floods with a return frequency of less than once in 100 years is not economically feasible. Since failure of the protection works would involve hazard to life and the likelihood of great physical damage, a flood with a return frequency of once in 100 years, the largest which can be economically justified, was selected as the basis for the design of levees and other structural features associated with the planned navigation and bank stabilization improvements. Key gaging stations on Red River used in determining the design flood were Fulton, Arkansas, Shreveport, Louisiana, and Alexandria, Louisiana. The flows for the design flood were based on hydrologic and hydraulic analyses of historic storms. The hydrologic tools employed to relate historic storms to historic floods are described in paragraph 20. Design flood discharges at key stations were derived from peak discharge frequency curves developed from analyses consisting of flow regulation and flood frequency studies as described in paragraph 22. The derivation of peak stages at the key stations for the design flood is described in paragraph 23. The flow line for the design flood was developed by relating the design stages at the key stations to other locations in accordance with experienced flow lines for major floods as discussed in subparagraph b. below. The process is such that the design flow line developed is not the result of a particular storm or series of storms.

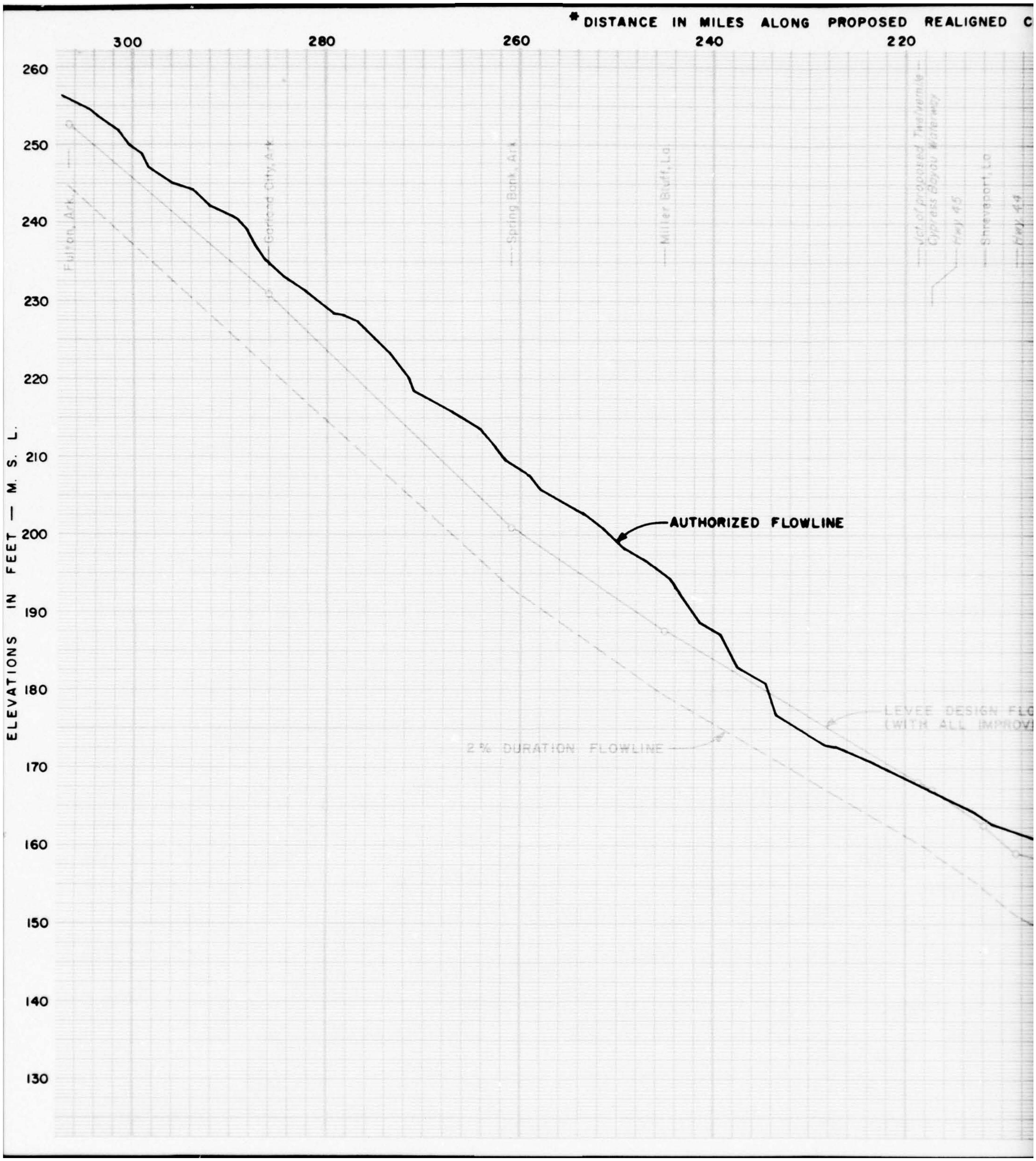
b. Design flow line.

(1) The design flow line, shown on figures 9 and 10, indicates the maximum stages that will occur at all locations along the Red River below Fulton for a flood of 1 percent exceedence frequency, (or a 100-year return frequency), under the conditions anticipated with planned navigation and bank stabilization improvements in place. This flow line reflects the influence of the Corps of Engineers authorized Hugo, Millwood, Boswell, Texarkana, and Ferrells Bridge Reservoirs. The planned bank stabilization and navigation improvements will effect a 2-foot lowering in stages from present conditions at bankfull and below bankfull stages on the Red River below Fulton. The lowering effect on stages for the design flow line is between 1 1/2 and 2 feet, depending on the degree of overbank flow at the particular location along the channel. Above Fulton, where steel jetties, similar to the Kellner type, are to be used extensively, the lowering effect on stages will be negligible, due to the increased channel roughness induced by the jetties. The

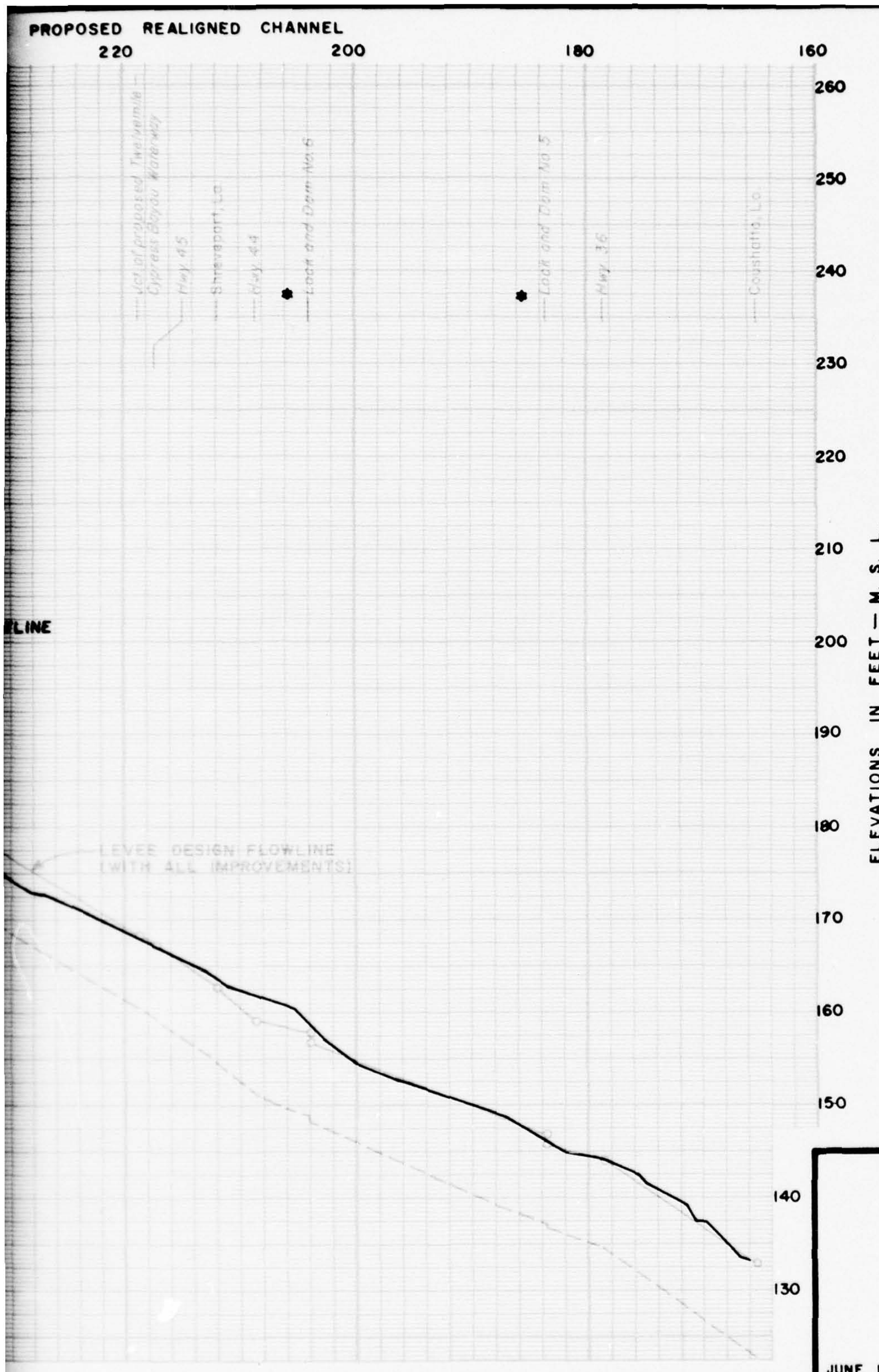
effect of the navigation dams will be to produce a 1-foot swellhead at each damsite. The backwater effect of the swellheads will extend only a relatively short distance upstream from the navigation dam.

(2) The stages of the design flow line on Red River were derived from the 100-year stages computed for the key gaging locations, by relating these stages to other locations in accordance with high water stages of the 1957 and 1958 floods, the most recent on Red River. The upper envelope of the high water surface profiles of these floods was used as a basis for interpolating design stages between the key locations. For the reach of the planned navigation waterway along Twelvemile and Cypress Bayous, from Daingerfield, Texas, to Shreveport, Louisiana, the stages of the design flow line in the vicinity of lock No. 7 were based on the maximum flood of record in Caddo Lake. This flood occurred in April-May 1958 under conditions which will not be materially changed by the proposed navigation improvements. The recurrence frequency of this flood was estimated to be on the order of 100 years. The design flow at lock No. 8 was based on a computed 100-year discharge for the 60-square mile uncontrolled drainage area between Ferrells Bridge Dam and the Old Highway No. 59 gage near Jefferson, Texas, and was based on discharge data obtained from the USGS Paper 1681, "Magnitude and Frequency of Floods ..., Lower Mississippi River Basin." To this value was added the 3,000 c.f.s. maximum controlled release (100-year frequency) from the Ferrells Bridge Reservoir to obtain the total 100-year discharge. The design flow line in the vicinity of lock No. 8 was based on the 100-year discharge determined above, experienced rating curves at the nearby Jefferson gage, and experienced flow lines in the vicinity of the lock.

(3) The levee design flow line is compared in figures 9 and 10 with: (a) the design flow line authorized as part of the general plan for flood control on Red River below Denison Dam; (b) the 2 percent flow line which is discussed in paragraph 23.b; and (c) the portion of the Mississippi River and Tributaries project flow line for the Red River below Boyce, Louisiana. The authorized flow line was developed on the assumption that a 20-inch runoff from the drainage area above Shreveport and a runoff 20 percent greater than that of the 1945 flood from the drainage area below Shreveport would extend over the same period as the 1945 flood with a similar runoff hydrograph. As a result this flow line, authorized by Public Law 526, 79th Congress, 2d Session, is based on a design flood greater in volume than that of the 1945 flood. The Mississippi River and Tributaries project flow line for the Red River below Boyce, Louisiana, was recommended for the Mississippi River and Tributaries project in House Document 308, 88th Congress, 2d Session, dated 21 May 1964.



* DISTANCE IN MILES ALONG PROPOSED REALIGNED C
300
280
260
240
220
260
250
240
230
220
210
200
190
180
170
160
150
140
130
ELEVATIONS IN FEET — M. S. L.
Fulton, Ark.
Garland City, Ark.
Spring Bank, Ark.
Miller Bluff, La.
Hwy 45
Shreveport, La.
Hwy 44
AUTHORIZED FLOWLINE
2% DURATION FLOWLINE
LEVEE DESIGN FL
(WITH ALL IMPROV



NOTE:
* Refers to realigned channel, locks, and dams proposed by the U.S. Army Corps of Engineers in the Comprehensive Basin Study— Interim Report on Navigation and Bank Stabilization.

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS

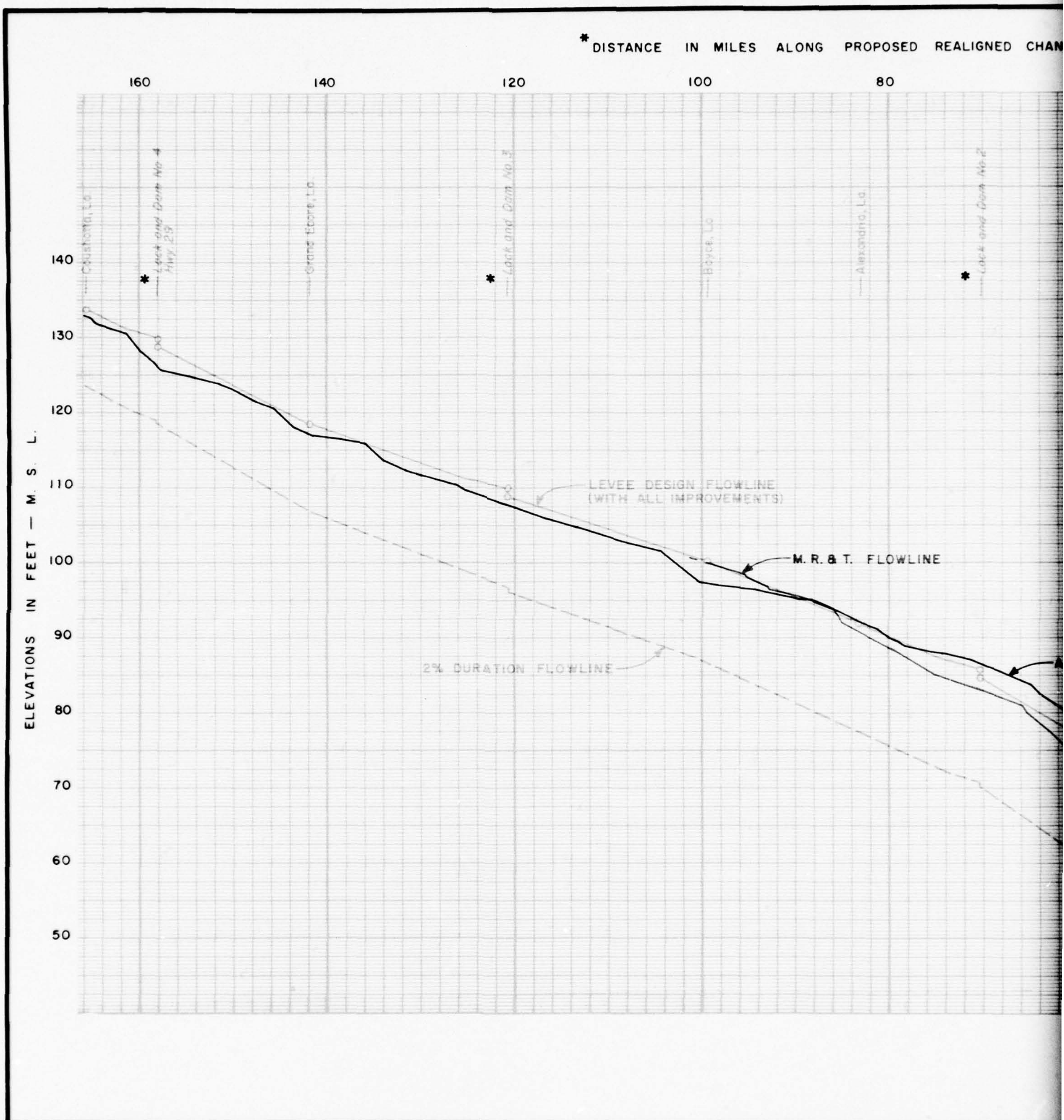
COMPREHENSIVE BASIN STUDY

COMPARATIVE WATER SURFACE PROFILES

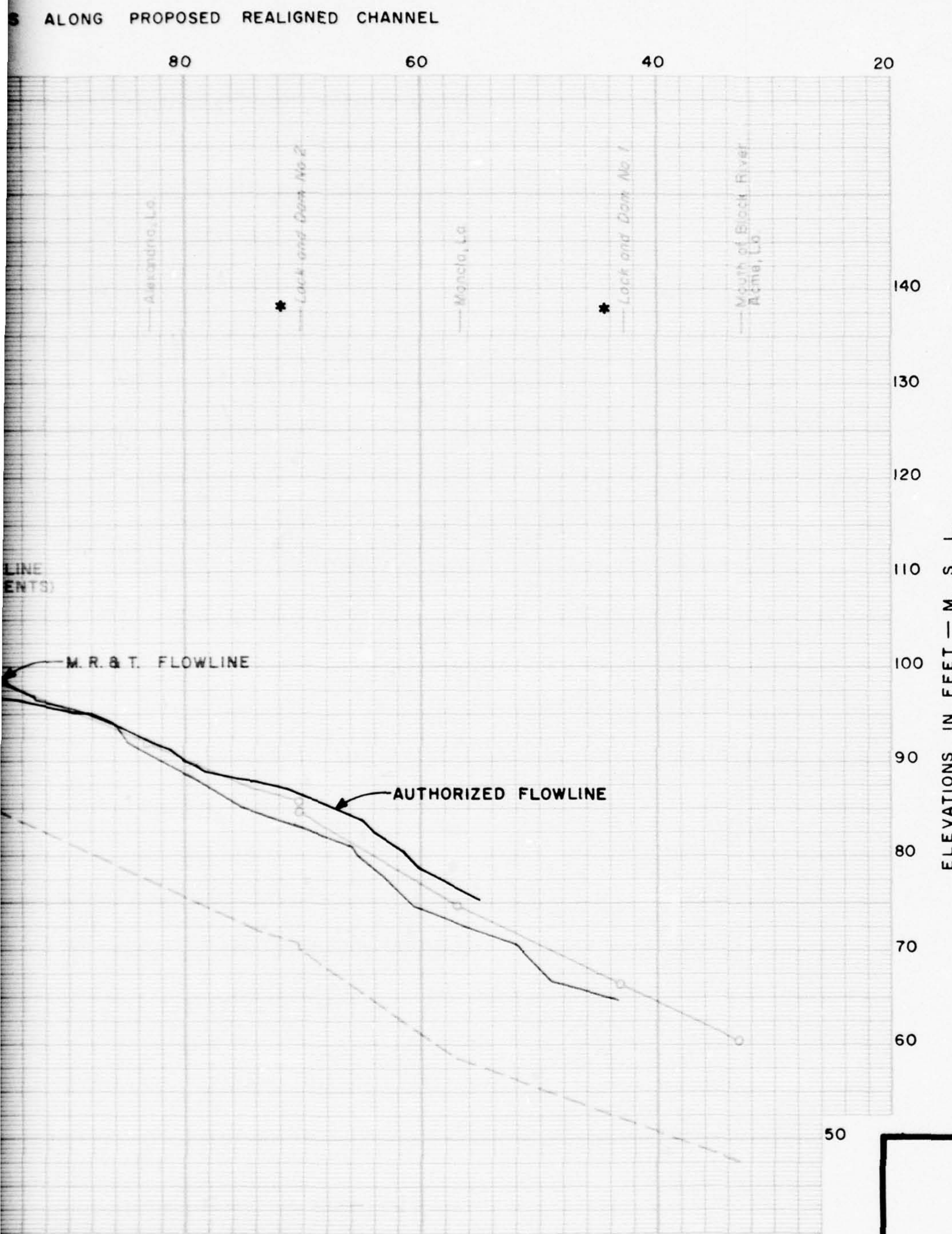
FULTON, ARK., TO COUSHATTA, LA.

JUNE 1968

FILE NO. H-2-24396



*DISTANCE IN MILES ALONG PROPOSED REALIGNED CHAN
160
140
120
100
80
140
130
120
110
100
90
80
70
60
50
ELEVATIONS IN FEET — M. S. L.
Coushatta, La.
*
Lock and Dam No. 4
Hwy 29
Grand Ecore, La.
*
Lock and Dam No. 3
Boyce, La.
Alexandria, La.
*
Lock and Dam No. 2
LEVEE DESIGN FLOWLINE
(WITH ALL IMPROVEMENTS)
M. R. & T. FLOWLINE
2% DURATION FLOWLINE



NOTE:
* Refers to realigned channel, locks, and dams proposed by the U.S. Army Corps of Engineers in the Comprehensive Basin Study — Interim Report on Navigation and Bank Stabilization.

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS

COMPREHENSIVE BASIN STUDY

COMPARATIVE WATER SURFACE PROFILES
COUSHATTA, LA., TO MONCLA, LA.

JUNE 1968 — FILE NO H-2-24396

FIGURE 10

c. Design stages and discharges. Contrary to most experienced floods, peak flows for the design flood increase in magnitude from upstream to downstream key stations. This situation results from the fact that confinement in the lower reaches of the river has been increasing, upstream reservoir construction has exerted, and will continue to exert a greater effect on upstream stations, and inflows for the design flood were critically arranged to produce peak discharges in the main stem. The design stages and discharges at the key locations and at lock and dam locations are shown in table 14. The design discharges for pertinent locations between key stations were obtained by interpolation based on tributary inflow entering the main stem.

22. FLOOD DISCHARGE-FREQUENCY ESTIMATES

a. Determination of design discharges. Curves representing the most probable relationships between annual flood peak discharges and exceedence frequencies were derived for the three key gaging stations for use in determining the magnitude of the design discharges. These peak discharge frequency curves are shown in figures 11 through 13. The design discharges were obtained directly from the regulated curve, which represents the peak discharge frequency relation anticipated under future conditions. In plotting the frequency curve, the peak discharges used were based on routing of historical floods under anticipated future conditions. Since frequency analyses of hydrologic data are based on the assumption of random occurrences, the peak discharge values reflecting the influence of manmade controls could not be analyzed by accepted frequency methods. Therefore, the unregulated curve of peak discharge frequency relations, which represents the frequency analysis of the historic floods routed to their natural or unregulated condition, was used to determine the exceedence frequency values corresponding to the peak discharge values for plotting the regulated curve.

b. Unregulated peak discharge-frequency curves. Flood frequency estimates for unregulated discharge conditions were based on 36 years of records (1928-1963) of annual maximum instantaneous peak discharges at the three key stations. Records at these stations earlier than 1928 were not used because of uncertainty of the modifying influences of levee crevasses, new levees constructed since 1928, and natural changes in river alignment and length. The statistical method of flood peak frequency computation described in the paper entitled "Statistical Methods in Hydrology," by Leo R. Beard, CW-151, January 1962, was used. Values of "log mean Q" of 5.080, 5.12, and 5.103 and "log standard deviation" of 0.208, 0.217, and 0.211, were computed for Fulton, Shreveport, and Alexandria, respectively, to determine the annual events curve indexes for the 36 years of unregulated peak discharge, assuming zero skew. The unregulated peak discharge curve was drawn from the annual events

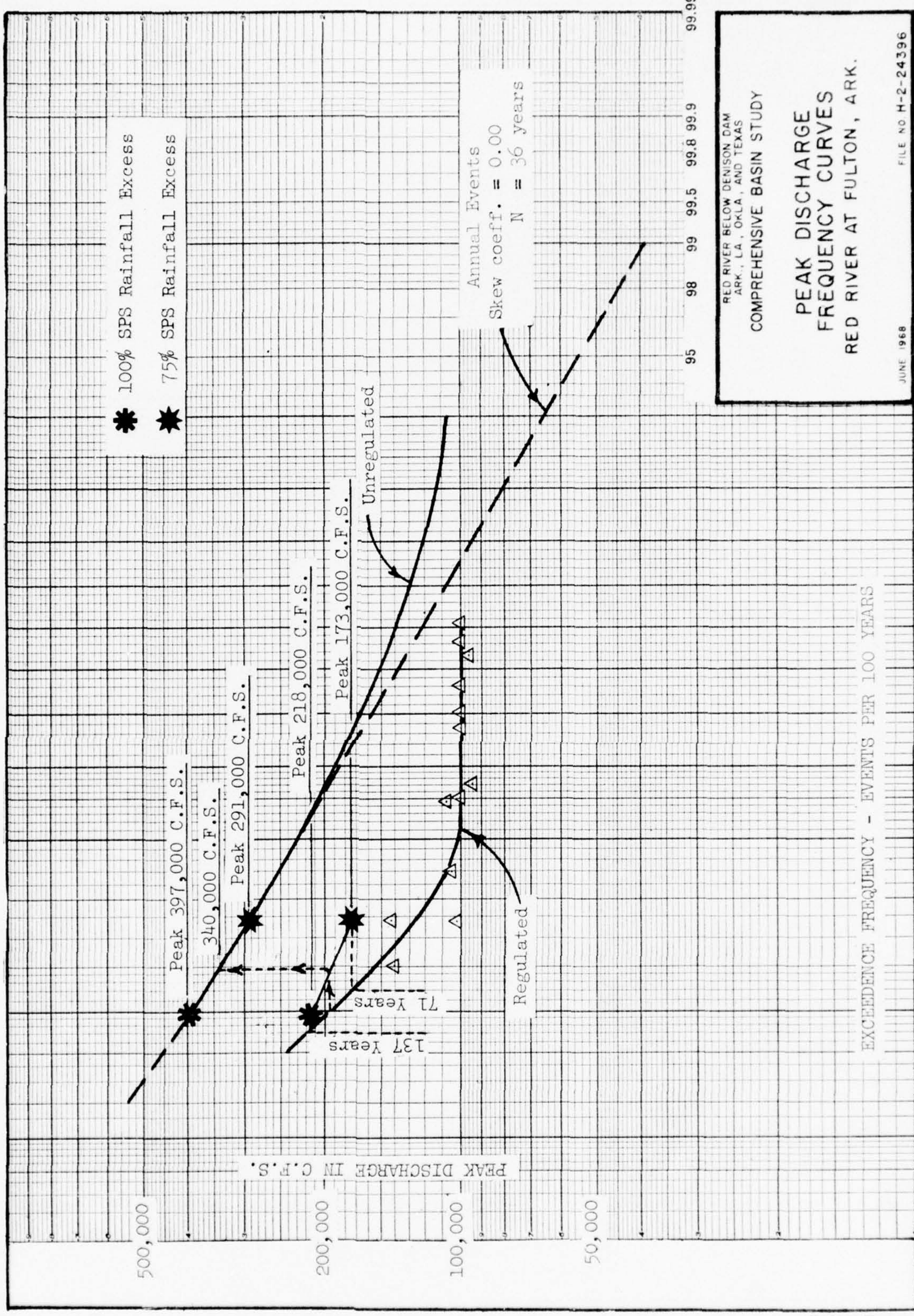
TABLE 14

PROJECT DESIGN STAGES AND DISCHARGES

RED RIVER AND NAVIGATION WATERWAY BELOW FULTON, ARKANSAS

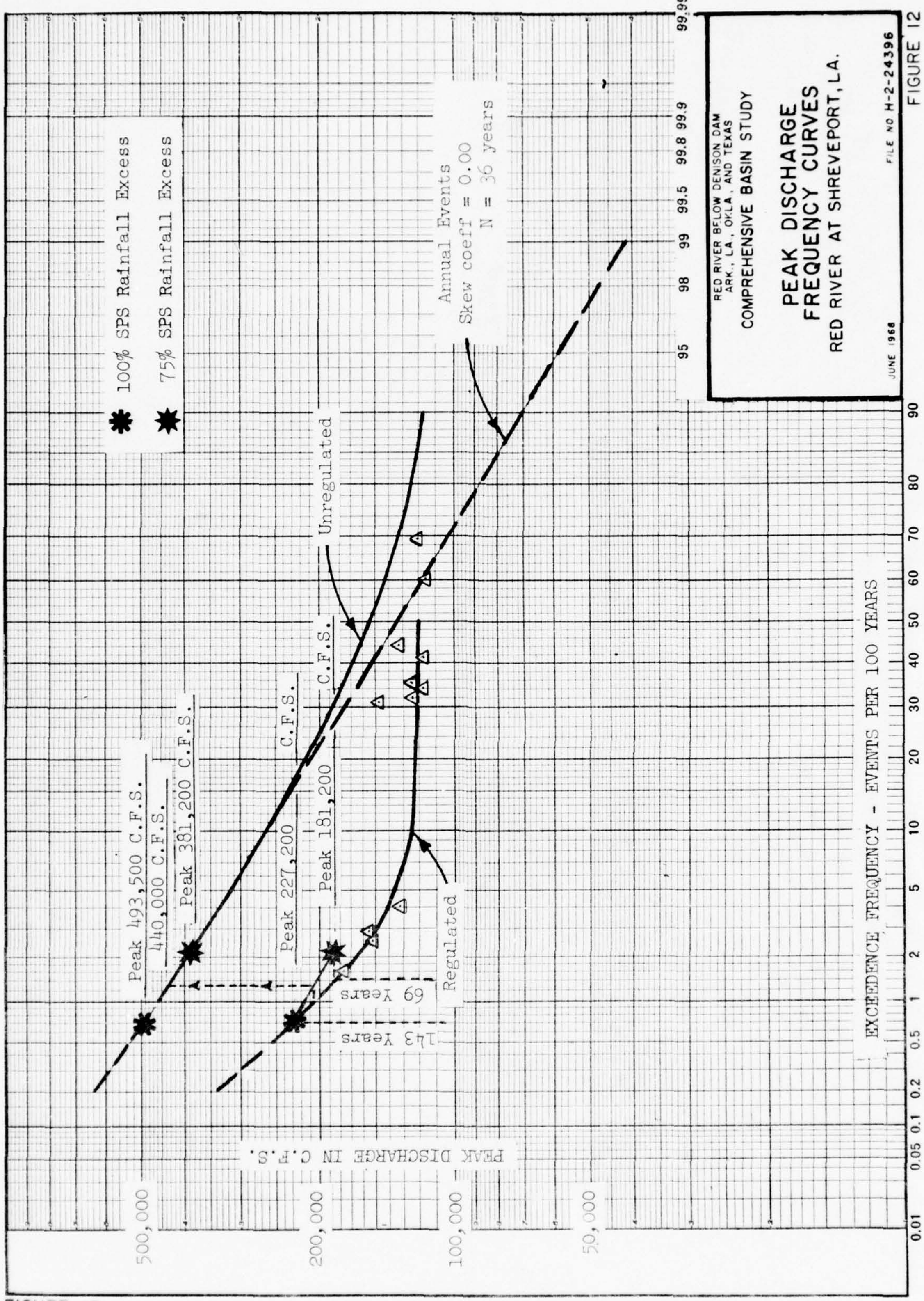
Lock No. (or) key station	Location mileage(1)	Stage Ft.-m.s.l. Upstream	Stage Ft.-m.s.l. Downstream	Discharge 1000 c.f.s.
RED RIVER MAIN STEM				
Fulton, Ark.	307.3	254.1	254.1	195
Shreveport	212.3	163.6	163.6	205
6	204.3	158.7	157.7	205
5	183.8	147.6	146.6	205
4	158.5	129.8	128.8	225
3	120.8	109.8	108.8	250
Alexandria, La.	84	91.9	91.9	255
2	70.3	85.6	84.6	255
1	42.8	66.5	66.5	255
RED RIVER TRIBUTARY, TWELVEMILE BAYOU AND CYPRESS BAYOU				
Caddo Lock	232.8	181.5	180.1	(2)
Jefferson Lock	267.2	192.0	191.0	17.5
Ferrells Bridge Lock	276.2	(3)	199.0	(2)

(1) Along realigned channel above mouth of Mississippi River.
(2) Not required for navigation structures design.
(3) Flood control pool El. 249.5
Surcharge pool El. 270.0



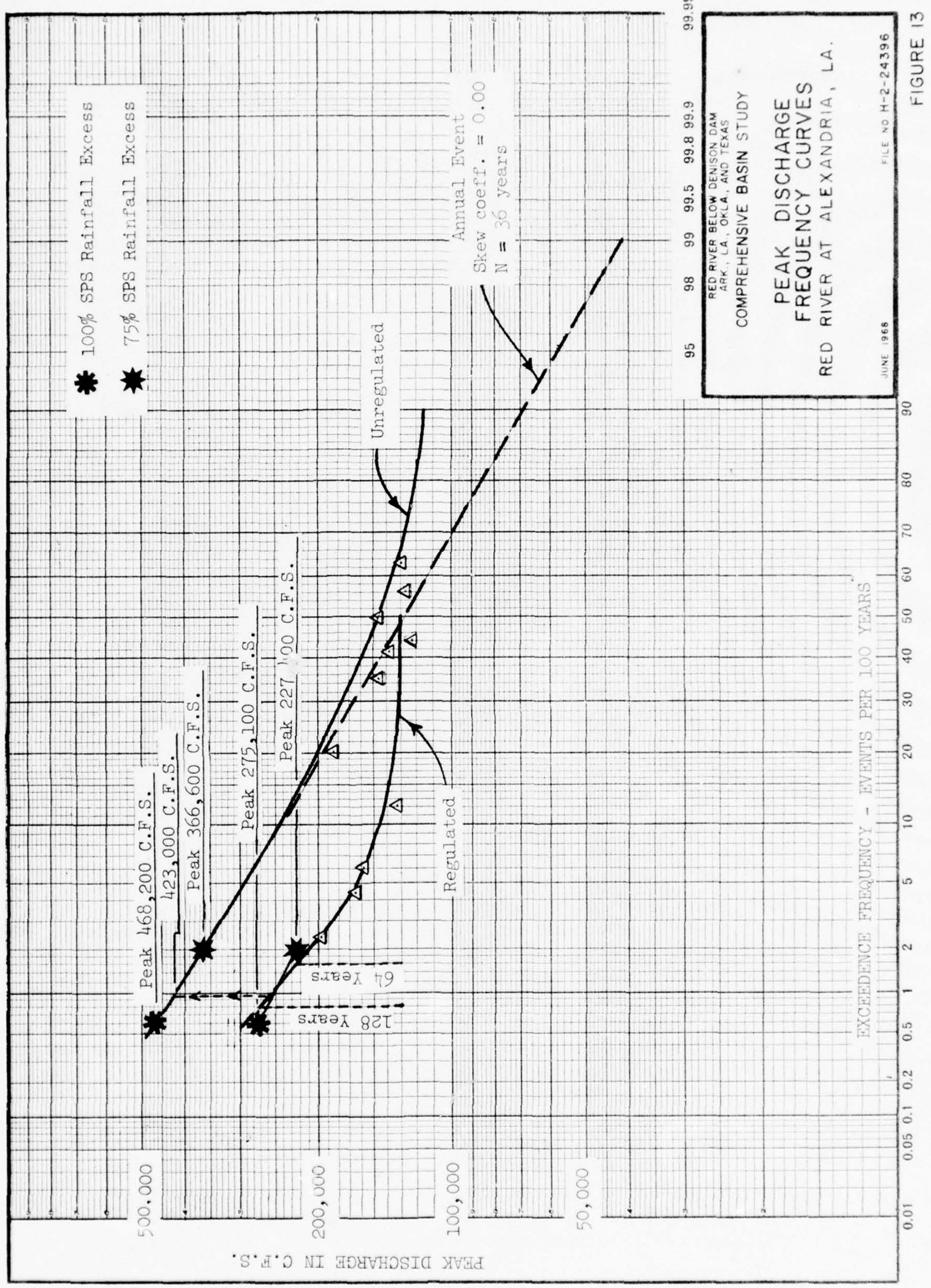
100% SPS Rainfall Excess
75% SPS Rainfall Excess
Peak 397,000 C.F.S.
340,000 C.F.S.
Peak 291,000 C.F.S.
Peak 218,000 C.F.S.
Peak 173,000 C.F.S.
Unregulated
Regulated
71 Years
137 Years
Annual Events
Skew coeff. = 0.00
N = 36 years
PEAK DISCHARGE IN C.F.S.
500,000
200,000
100,000
50,000
EXCEEDENCE FREQUENCY - EVENTS PER 100 YEARS
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
99.99
RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
PEAK DISCHARGE
FREQUENCY CURVES
RED RIVER AT FULTON, ARK.
JUNE 1968
FILE NO H-2-24396
FIGURE 11

FIGURE 11



100% SPS Rainfall Excess
75% SPS Rainfall Excess
Peak 493,500 C.F.S.
440,000 C.F.S.
Peak 381,200 C.F.S.
Peak 227,200 C.F.S.
Peak 181,200 C.F.S.
Unregulated
Regulated
69 Years
143 Years
Annual Events
Skew coeff = 0.00
N = 36 years
PEAK DISCHARGE IN C.F.S.
500,000
200,000
100,000
50,000
EXCEEDENCE FREQUENCY - EVENTS PER 100 YEARS
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
99.99
RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
PEAK DISCHARGE
FREQUENCY CURVES
RED RIVER AT SHREVEPORT, LA.
JUNE 1968
FILE NO H-2-24396
FIGURE 12

FIGURE 12



100% SPS Rainfall Excess
75% SPS Rainfall Excess
Annual Event
Skew coeff. = 0.00
N = 36 years
Unregulated
Regulated
Peak 468,200 C.F.S.
423,000 C.F.S.
Peak 366,600 C.F.S.
Peak 275,100 C.F.S.
Peak 227,_00 C.F.S.
64 Years
128 Years
500,000
200,000
100,000
50,000
PEAK DISCHARGE IN C.F.S.
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
99.99
EXCEEDENCE FREQUENCY - EVENTS PER 100 YEARS
RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
PEAK DISCHARGE
FREQUENCY CURVES
RED RIVER AT ALEXANDRIA, LA.
JUNE 1968
FILE NO H-2-24396
FIGURE 13

FIGURE 13

values, modified according to the likeliness concept, and further adjusted for the corresponding partial duration values using the Langbein criteria.

c. Regulated peak discharge-frequency curves. In deriving reservoir-modified or regulated discharge-frequency curves, it was assumed that the exceedence frequency of the peak discharges for each of the floods analyzed, as determined from the unregulated discharge-frequency curve, would remain unchanged under regulated flow conditions. Therefore, the regulated peak discharge-frequency curve was drawn by assigning to the values of the regulated peak discharges for each flood the same exceedence frequencies as were assigned to the unregulated peak discharges for the same flood.

d. Derivation of flow conditions. The peak discharges for the unregulated and regulated flow conditions by water years for the study period and the corresponding recurrence frequencies are shown for the key stations in tables 15, 16, and 17. Also shown in the tables are the peak discharges and exceedence frequencies for the standard project floodflows. Standard project storm inflows were routed under both regulated and unregulated conditions to provide a basis for extending the regulated peak discharge-frequency curve beyond the range of the exceedence frequencies indicated by analysis of the historic floods above. The unregulated floodflows were developed assuming that no reservoirs were in place in the Red River Basin but that all authorized levees were in place. The regulated floodflows were developed assuming all authorized levees and reservoirs in place. For computing reservoir outflows, full use was made of hypothetical reservoir operations based on an analysis of the floods of record. All routings were based on the present conditions of river channel and overbank, since the peak flows of floods of record since 1928 would not be significantly influenced by the proposed changes in the river channel and floodway.

e. Routing methods to modify flows. Two methods of flood routing were used to modify the flow hydrographs of the historic floods at the key stations of Fulton, Shreveport, and Alexandria to desired flow conditions: the progressive average-lag method and the coefficient (Muskingum) method. These methods are described in the Corps of Engineers EM 1110-2-1408, dated 1 March 1960. Except for major floods, the progressive average-lag method was used to modify floods to the unregulated conditions; the coefficient method was used to modify the major floods to the unregulated conditions and to modify all floods to the regulated conditions.

f. Progressive average-lag routing method. The routing constants of this method are shown in table 18. These routing constants were developed for the economic studies of presently authorized reservoirs in the Red River system. The progressive average-lag method was considered satisfactory only for modifying to the unregulated

TABLE 15

FLOOD PEAK DISCHARGE-FREQUENCY AT FULTON, ARK.

Water year	Unregulated peak disch. (1000 c.f.s.)	Exceedence freq. (events per 100 yrs.)	Regulated peak disch. (1000 c.f.s.)
1928	79		
1929	113		
1930	130		
1931	54		
1932	145		
1933	80		
1934	55		
1935	161		
1936	72		
1937	72		
1938	338	2.0	140
1939	80		
1940	85		
1941	144	46.0	100
1942	208	14.5	108
1943	111		
1944	147	43.0	97
1945	290	3.8	142
1946	148		
1947	199	17.0	95
1948	106		
1949	206	15.0	100
1950	158	36.0	100
1951	166	30.0	101
1952	171	27.0	100
1953	137	51.0	100
1954	126		
1955	88		
1956	85		
1957	293	3.7	101
1958	253	6.5	105
1959	83		
1960	91		
1961	96		
1962	85		
1963	52		
SPF	[illegible]	0.90	218

N = 36 years
Log Mean Discharge = 5.080
Log Standard Deviation = 0.208
Skew Coefficient = 0.0

TABLE 16

FLOOD PEAK DISCHARGE-FREQUENCY AT SHREVEPORT, LA.

Water year	Unregulated peak disch. (1000 c.f.s.)	Exceedence freq. (events per 100 yrs.)	Regulated peak disch. (1000 c.f.s.)
1928	94		
1929	121		
1930	243		
1931	63		
1932	168		
1933	76		
1934	71		
1935	181		
1936	86		
1937	94		
1938	330	4.0	132
1939	89		
1940	96		
1941	143	60.0	116
1942	183	32.0	124
1943	93		
1944	163	44.0	132
1945	416	1.6	177
1946	132	69.0	120
1947	158		
1948	119		
1949	179	32.0	118
1950	177	35.0	125
1951	151		
1952	168	41.0	118
1953	185	31.0	149
1954	121		
1955	96		
1956	59		
1957	377	2.5	151
1958	365	2.7	155
1959	94		
1960	152		
1961	124		
1962	84		
1963	55		
SPF	494	0.70	227

N = 36 years
Log Mean Discharge = 5.12
Log Standard Deviation = 0.217
Skew Coefficient = 0.0

TABLE 17

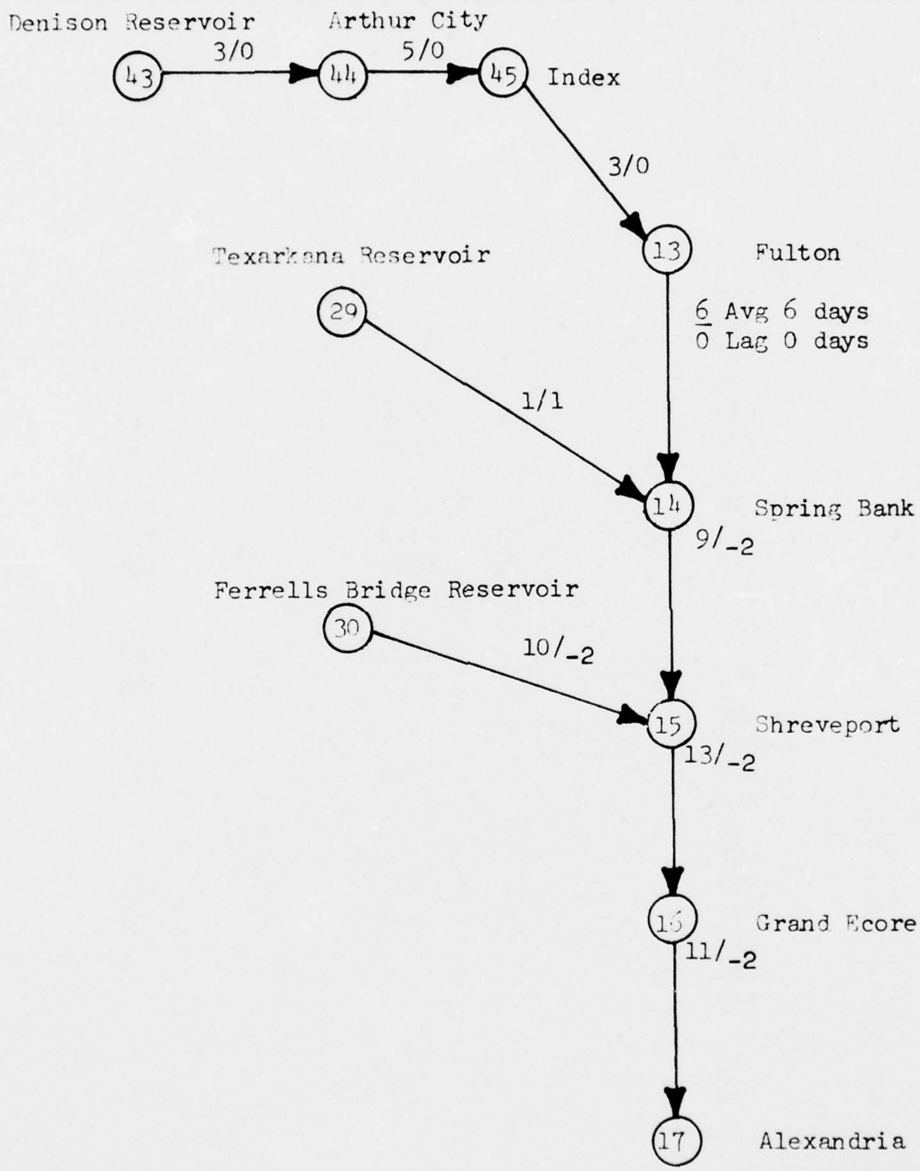
FLOOD PEAK DISCHARGE-FREQUENCY AT ALEXANDRIA, LA.

Water year	Unregulated peak disch. (1000 c.f.s.)	Exceedence freq. (events per 100 yrs.)	Regulated peak disch. (1000 c.f.s.)
1928	93		
1929	103		
1930	151		
1931	74		
1932	194		
1933	91		
1934	83		
1935	151		
1936	75		
1937	107		
1938	232	12.0	131
1939	92		
1940	89		
1941	132	62.5	129
1942	156	41.0	138
1943	84		
1944	146	49.0	145
1945	346	2.4	197
1946	139	56.0	126
1947	160		
1948	133		
1949	152	44.0	122
1950	167	34.5	144
1951	136		
1952	146		
1953	200	2.0	184
1954	111		
1955	91		
1956	68		
1957	300	4.5	164
1958	278	6.0	157
1959	91		
1960	135		
1961	138		
1962	113		
1963	53		
SPF	468	0.60	275

N = 36 years
Log Mean Discharge = 5.103
Log Standard Deviation = 0.211
Skew Coefficient = 0.0

TABLE 18

PROGRESSIVE AVERAGE-LAG METHOD OF FLOOD ROUTING
RED RIVER BELOW DENISON DAM



conditions, minor floods, and other lesser magnitude annual floods which occurred under conditions regulated by reservoir operation. The procedure for using this method consisted of routing the holdouts of reservoirs in operation during a given flood to the key stations of Fulton, Shreveport, and Alexandria and algebraically applying the routed holdouts to flood hydrographs at each of the key stations to obtain the unregulated hydrograph. From 1945 through 1956, only Denison Reservoir was in operation; during 1957, Denison and Texarkana Reservoirs were in operation; and from 1958 through 1963, Denison, Texarkana, and Ferrells Bridge Reservoirs were in operation.

g. Coefficient routing method. The routing constants for this method are shown in table 19 and figure 34 shows the routing schematic. The coefficient method of routing was used on the Red River below Fulton to determine the regulating effects of the existing Texarkana and Ferrells Bridge Reservoirs at the key stations of Fulton, Shreveport, and Alexandria for the floodflows of the major floods of 1938, 1945, 1953, 1957, 1958, for the standard project flood, and for the minor floods of 1941, 1942, 1944, 1946, 1949, 1950, and 1952. This method was also used to determine the unregulated hydrographs at these key stations for the major floods. The influence of crevasses on the peak discharges of floods which occurred in 1938 and 1945 was eliminated assuming confined conditions for all floods. The routing coefficients were developed by the inverse-routing procedure described in the referenced manual using the experienced and reproduced hydrographs at Shreveport and Alexandria for the 1958 flood. (See figures 14 and 15.) In the procedure, the inflows from the main channel and tributary inflows between key stations were compared, mathematically, with the total discharge hydrograph at the outflow station to develop the values of "flood wave" travel time (K) and the dimensionless constant (X) using a routing period (Δ T) equal to 1 day. The routing coefficients shown in table 19 for intermediate gaging stations at Garland City and Springbank, Arkansas, and Coushatta and Grand Ecore, Louisiana, were determined by relating the "flood wave" travel times (K) between the key stations to the travel distances (reach mileage) of the intermediate stations from the key stations.

23. DETERMINATION OF DESIGN STAGES

a. Design stage-discharge relations. The design rating curves for the key stations of Fulton, Shreveport, and Alexandria are shown on figures 16, 17, and 18, respectively. These curves were derived by analysis of the long-term rating curves for major floods subsequent to 1945, and incorporate both the stage lowerings which will result from the channel improvements described in the Interim Report and the lowerings which will result from the construction of the remaining authorized reservoirs. For each station, the new design elevation was determined by entering the stage-discharge relationship with the design discharge.

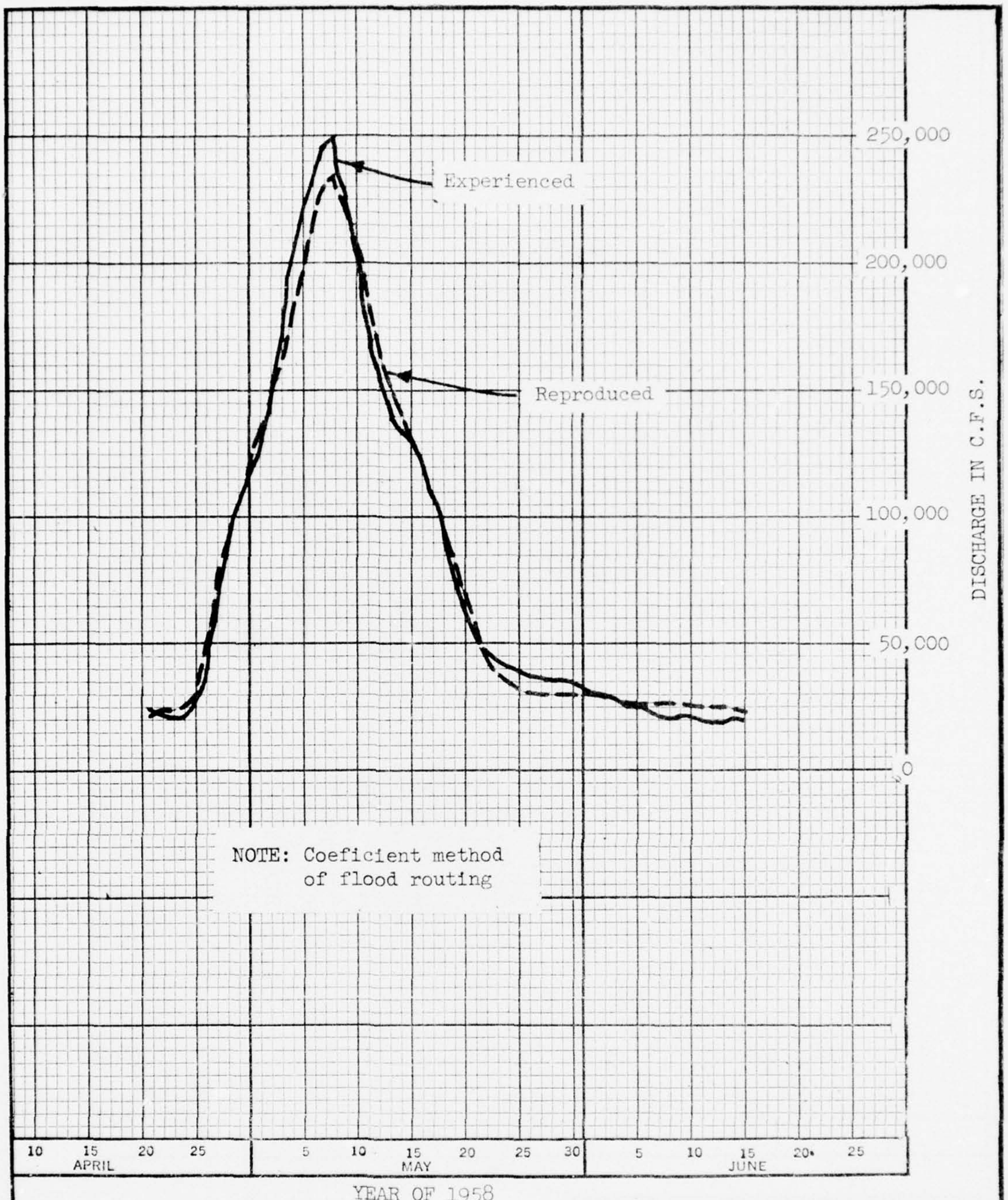
TABLE 19

ROUTING CONSTANTS OF COEFFICIENT (MUSKINGUM) METHOD

RED RIVER: FULTON, ARKANSAS TO ALEXANDRIA, LOUISIANA

Station	1957 mileage	Reach miles	Routing constants: K	X	ΔT	Disch. range in 1000 c.f.s.
Fulton	405					
		33	0.7	0	1	All
Garland City	372					
		37	0.8	0	1	All
Springbank	335					
		58	1.0	-0.1	1	All
Shreveport	277					
		59	2.0	0	1	All
Coushatta	218					
		37	1.0	-0.1	1	0-99
		37	1.0	0	1	100-149
		37	2.0	+0.1	1	150 and above
Grand Ecore	181					
		78	2.0	-0.1	1	0-99
		78	3.0	0	1	100-149
		78	4.0	+0.1	1	150 and above
Alexandria	103					

NOTE: Routing Schematic shown on figure 34.

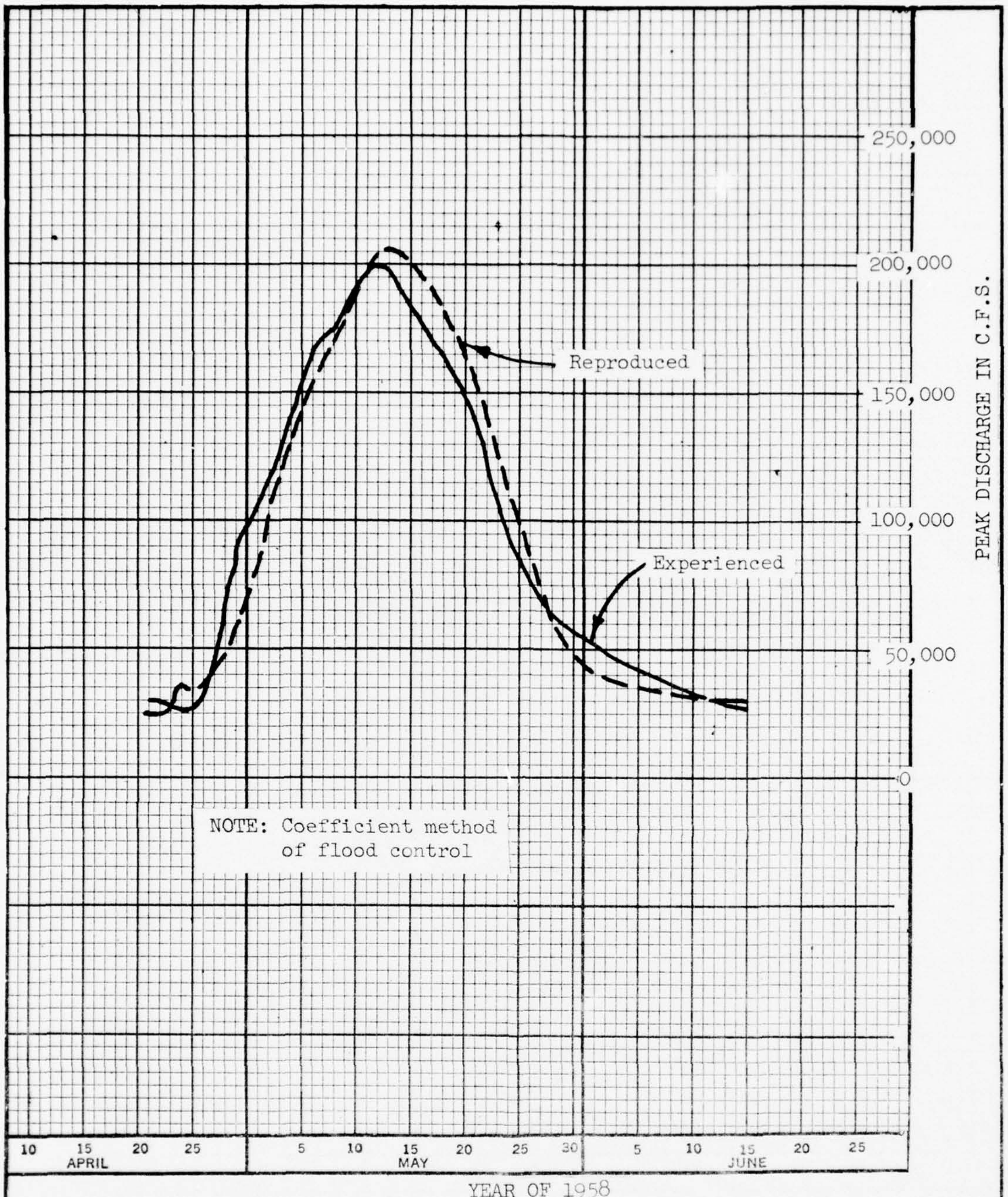


RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

EXPERIENCED AND REPRODUCED HYDROGRAPHS
RED RIVER AT SHREVEPORT, LA.

JUNE 1968 FILE NO. H-2-24396

FIGURE 14

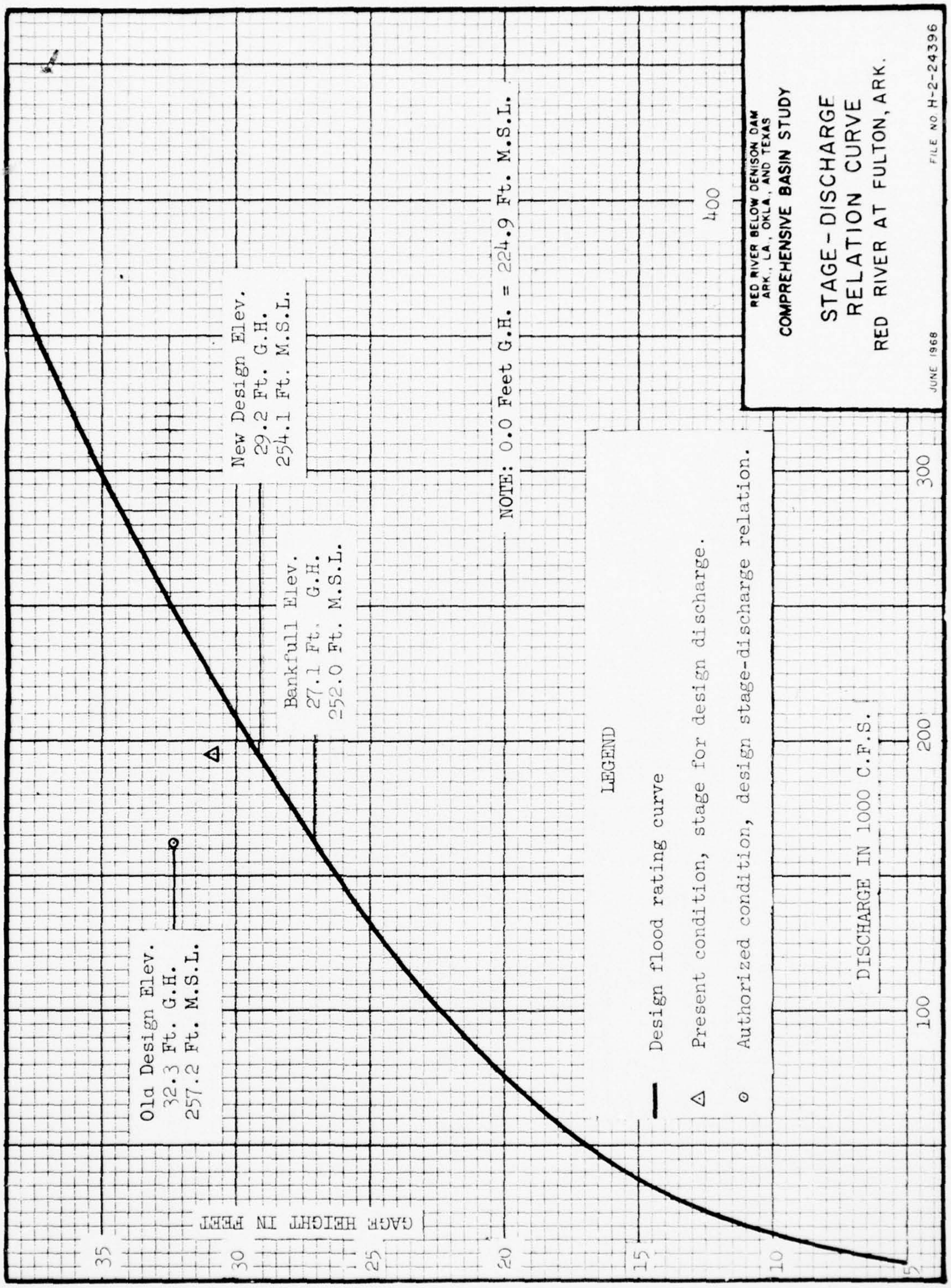


RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

EXPERIENCED AND REPRODUCED HYDROGRAPHS
RED RIVER AT ALEXANDRIA, LA.

JUNE 1968 FILE NO. H-2-24396

FIGURE 15



Old Design Elev.
32.3 Ft. G.H.
257.2 Ft. M.S.L.
New Design Elev.
29.2 Ft. G.H.
254.1 Ft. M.S.L.
Bankfull Elev.
27.1 Ft. G.H.
252.0 Ft. M.S.L.
NOTE: 0.0 Feet G.H. = 224.9 Ft. M.S.L.
LEGEND
Design flood rating curve
Present condition, stage for design discharge.
Authorized condition, design stage-discharge relation.
GAGE HEIGHT IN FEET
35
30
25
20
15
10
5
DISCHARGE IN 1000 C.F.S.
100
200
300
400
RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
STAGE-DISCHARGE
RELATION CURVE
RED RIVER AT FULTON, ARK.
JUNE 1968
FILE NO H-2-24396
FIGURE 16

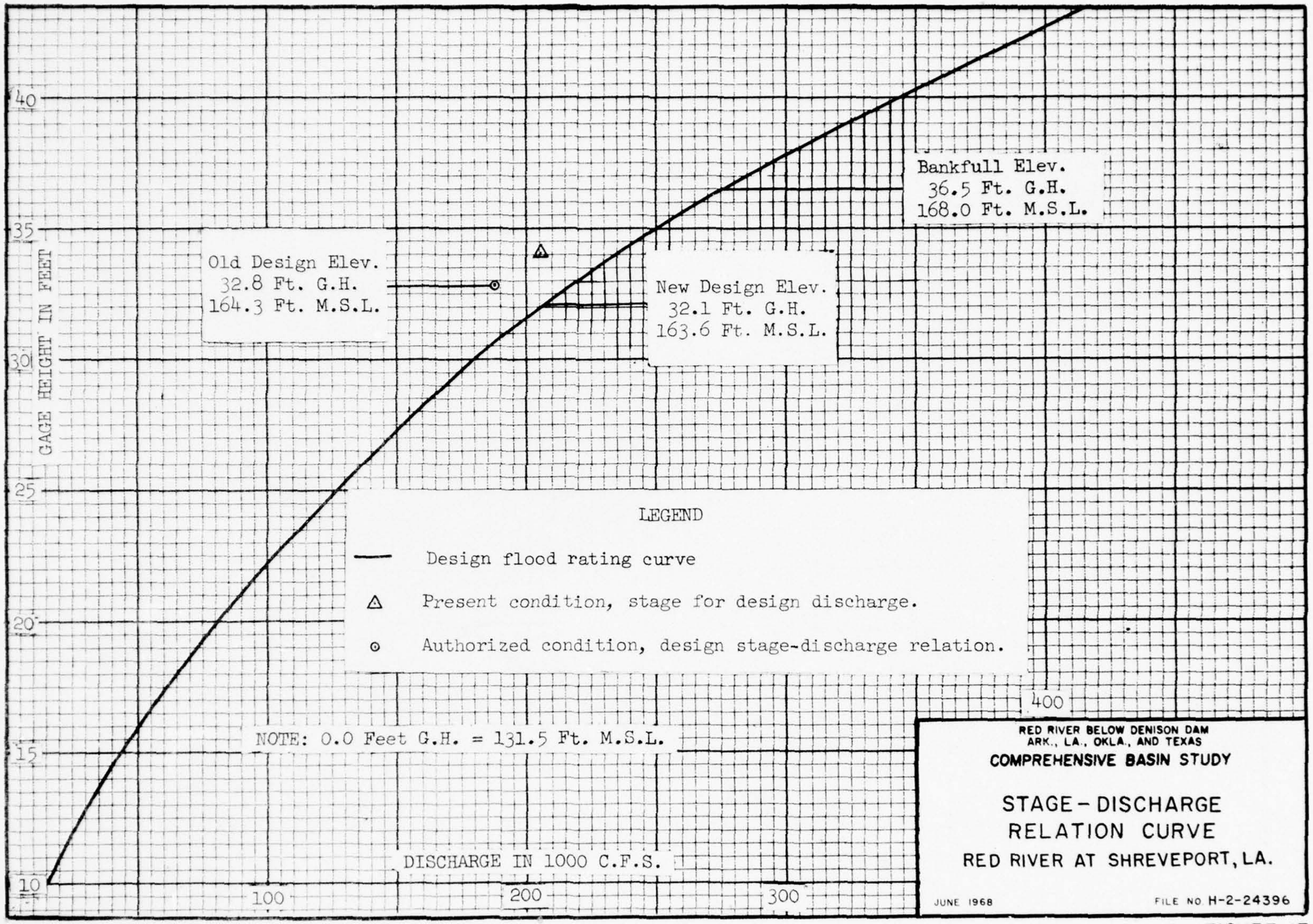

Old Design Elev.
32.8 Ft. G.H.
164.3 Ft. M.S.L.
New Design Elev.
32.1 Ft. G.H.
163.6 Ft. M.S.L.
Bankfull Elev.
36.5 Ft. G.H.
168.0 Ft. M.S.L.
LEGEND
Design flood rating curve
Present condition, stage for design discharge.
Authorized condition, design stage-discharge relation.
NOTE: 0.0 Feet G.H. = 131.5 Ft. M.S.L.
GAGE HEIGHT IN FEET
DISCHARGE IN 1000 C.F.S.
10
15
20
25
30
35
40
100
200
300
400
RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
STAGE - DISCHARGE
RELATION CURVE
RED RIVER AT SHREVEPORT, LA.
JUNE 1968
FILE NO H-2-24396
FIGURE 17

FIGURE 17

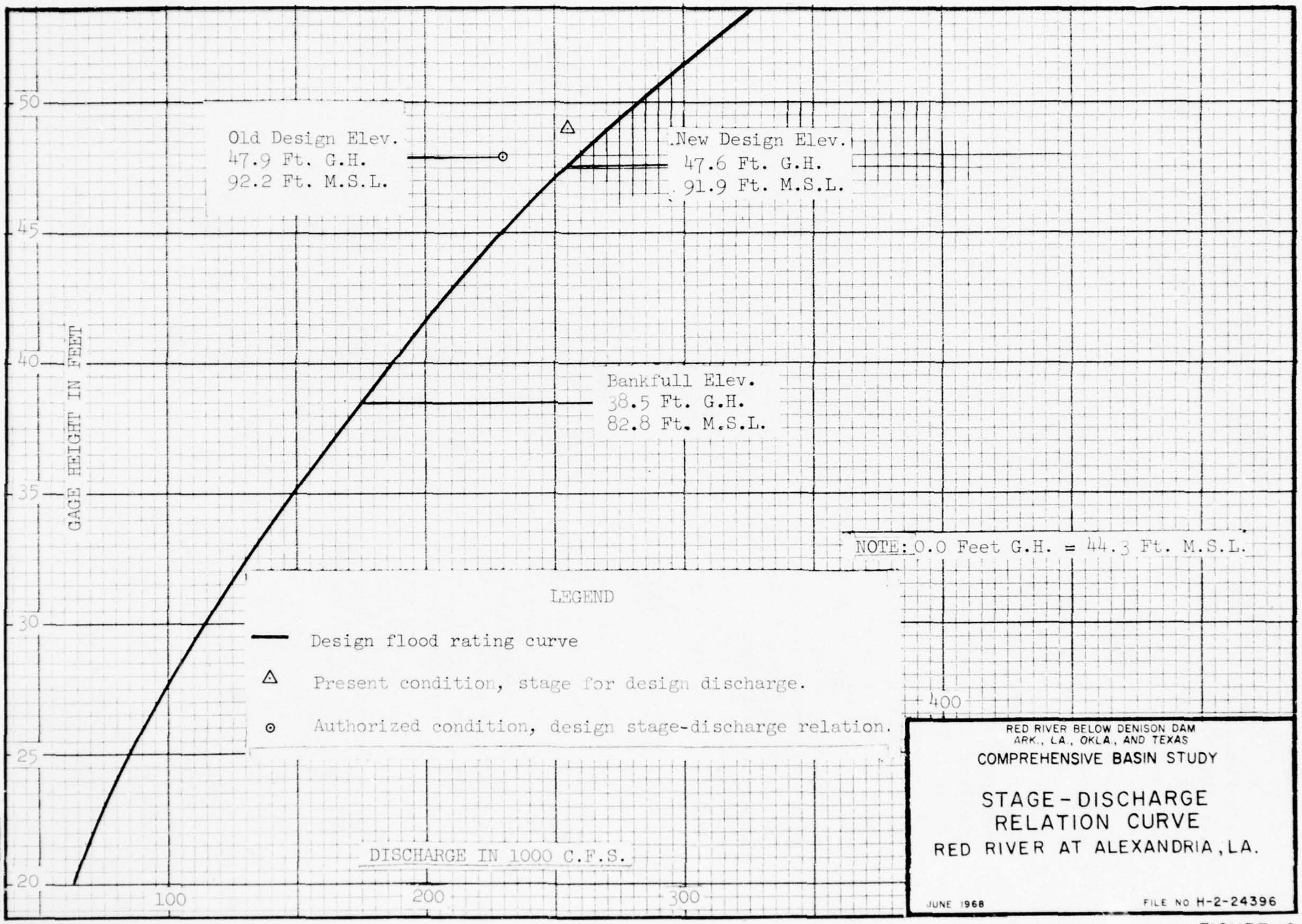


FIGURE 18

FIGURE 18

b. Derivation of 2 percent flow line. Discharge duration data were available for the regulated flow condition which was computed for the three key gaging stations on Red River. A family of discharge duration profiles was plotted. Adjustments were made between the key locations to reflect the increased flows contributed by the intervening tributaries proportionate to the percent control of their respective drainage area. From this family of profiles, discharge duration curves were drawn for several desired points between Fulton and lock No. 1 on Red River where flow data were unavailable. Using the discharge duration curves the 2 percent discharge value was obtained. Stage-discharge curves for ungaged key locations were developed from the design flow line studies. From the curve at each location the stage corresponding to the 2 percent discharge was obtained. For the reach of the navigation waterway along Twelvemile and Cypress Bayous, from Daingerfield, Texas, to its junction with Red River, the 2 percent duration flow line included an analysis of the records of daily stages at Cypress Creek near Jefferson, mile 265. The data at this gage were correlated with 2 percent duration stages at Ferrells Bridge Dam, Caddo Lake Dam, and Red River at its junction with Twelvemile Bayou to obtain the 2 percent duration flow line. The data at Ferrells Bridge Dam were available from design studies; at Caddo Lake Dam, the data were estimated; and at Red River, the data were available from the duration studies along Red River. The 2 percent flow line is shown on figures 9 and 10.

24. SEDIMENTATION STUDIES

The annual sediment load of Red River is high. The volume of soil entering the river between Denison Dam and Shreveport from bank caving alone is indicated to be about 61,300,000 cubic yards a year. Observations of sediment in suspension have been made periodically at various stations on the river proper and certain tributaries. At most of the stations, 10 or more years of record are available. In the analysis suspended sediment was broken down into sand and silt fractions. The sand fraction consists of all particles coarser than 0.0625 mm. and the silt fraction, which includes clay particles, consists of all particles finer than 0.0625 mm. The following summary table presents the average sediment regimen expected to be obtained when all authorized reservoirs are in operation.

RED RIVER SEDIMENT LOADS BY REACHES
(All authorized reservoirs in operation)

Below Denison Reservoir	Average Suspended Sediment in Transport In Million Tons/Year		
	Sand	Silt	Total
Tributaries above Arthur City	0.2	0.5	0.7
Total passing Arthur City*	1.7	4.4	6.1
Tributaries, Arthur City-Index	0.3	0.6	0.9
Total passing Index*	7.0	18.0	25.0
Tributaries, Index-Shreveport	0.1	0.5	0.6
Total passing Shreveport	7.7	24.3	32.0
Tributaries, Shreveport-Alexandria	0.0	0.3	0.3
Total passing Alexandria*	8.5	28.5	37.0
Tributaries below Alexandria	0.2	0.7	0.9
Total passing mouth of Red River (Simmesport)*	9.2	30.8	40.0

*Observation station.

The quantities actually measured are the totals passing the several main river observation stations. The total contributions of the tributaries were determined on the bases of volume, velocity of flow, drainage area size, and geographic characteristics. The samples secured in the course of the observations were separated into their sand and silt fractions.

Using 100 lbs./cu. ft. for weight of sand and 65 lbs./cu. ft. for silt, the volume in suspension passing Shreveport annually as indicated by the table, would be about 5,700,000 cubic yards of sand, and 27,600,000 cubic yards of silt; a total of 33,300,000 cubic yards. Of this total, tributary streams above Shreveport contribute about 74,000 cubic yards of sand and 568,000 cubic yards of silt, or a total of 642,000 cubic yards. The remainder, 32,700,000 cubic yards, is little more than half of the yardage caving into Red River annually between the two points.

Although local changes do occur, an alluvial river tends to maintain substantially the same width over the years, because erosion in bends is accompanied by accretion on points. Thus, the indication is that the only source of continuing discharge of sediment from the downstream end of a reach would be inflow of sediment from tributaries into the reach. Insofar as Red River is concerned, however, two other sources of sediment exist. One is a continuing depression of the streambed, and the other, which is

related to the first, is the failure of the alluviation process after bank caving to restore the banks to their former elevation. This latter effect is of particular significance above Shreveport. The alluvial banks in this reach reflect a regimen which was obtained prior to 1873. In that year, a massive natural obstruction in the river near Shreveport, known as the Red River Raft, was removed, inducing a depression in the streambed elevation of as much as 14 feet. This depression in turn induced a major reduction in flood heights, and, concomittantly, the restoration of caved banks to elevations considerably below those obtained prior to caving.

To gain some quantitative knowledge of the influence of the above phenomenon, a study was made in 1958 of 28 miles of the river (mile 193 to mile 221). Comparison of transverse sections from the surveys of 1930 and 1950 showed that the average bankfull elevation had decreased 2.3 feet during the 20-year period, during which the river had shifted its position by at least its own width throughout the 28 miles. The amplitude of shift varied greatly, of course, from point to point. The study indicated a loss due to reduction in elevation of adjacent banks, of 72,800 cubic yards per mile of river per annum. From Shreveport to Fulton, this would indicate an annual loss of 9,848,000 cubic yards. From Fulton to Denison Dam, computed on the same basis, the indicated loss would be 9,828,000 cubic yards a year. Because of the somewhat lower banks, slightly narrower channel, and the smaller annual acreage losses per mile of river from bank caving for the Fulton-Denison reach as compared with the Fulton-Shreveport reach, the 9,828,000 figure for the Fulton-Denison reach is conservative.

Under the impetus of forces resulting from the removal of the Red River Raft, the riverbed at Shreveport was progressively deepened as the stream sought to establish a new equilibrium. Based on surveys and discharge and stage data for the period 1928 to 1945, the rate of streambed depressions was about 0.12 foot per year. For an average streambed width of 800 feet, the above represents a loss of about 19,000 cubic yards per annum. The improvements described in the Interim Report involve extensive realignment of the river channel which will effect a substantial reduction in overall length. The steepening of the streambed resulting from the reduction in length will, to some extent, persist, inasmuch as the shortened alignment will be maintained. Further, all flow will not be confined to the realigned channel, since, at moderately high stages and above, the flow in old bendways will be considerable. If half of the indicated bed lowering needed to regain present slopes is assumed to occur over a period of 100 years, the annual volume removed in the process would be (a) with the proposed improvements constructed to Denison Dam: 7,680,000 cubic yards; (b) with the work completed to Index: 2,500,000 cubic yards; and (c) with no work above Shreveport: 1,450,000 cubic yards.

AD-A036 743 RED RIVER BASIN COORDINATING COMMITTEE NEW ORLEANS LA F/G 8/6
COMPREHENSIVE BASIN STUDY. RED RIVER BELOW DENISON DAM, ARKANSA--ETC(U)
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Considering the proposed navigation improvements alone, the net annual volumes of sediment added to the reach below Shreveport after deducting bed lowering effects within the reach itself would be:

Condition (a) All proposed improvements below Denison Dam completed.

Net yardage due to bed lowering	4,800,000
Yardage from tributaries	3,400,000
	8,200,000

Condition (b) All proposed improvements below Index completed.

Net yardage from bed lowering	- 400,000
Yardage from tributaries	3,400,000
Yardage from bank erosion above Index	9,828,000
	12,828,000

Condition (c) Navigation improvements only completed.

Yardage due to bed lowering	-1,450,000
Yardage from tributaries	3,400,000
Yardage from bank erosion	19,656,000
	21,606,000

The foregoing estimates include bedload as well as suspended sediment. Assuming that the sand fraction still would be only 25 percent of the total, as shown by analysis of suspended sediment samples in the tabulation on page III-95, the net volumes of sand to be handled in the reach would be about 2,050,000 cubic yards, 3,207,000 cubic yards, and 5,402,000 cubic yards for conditions (a), (b), and (c), respectively. The close agreement of the latter figure with the 5,700,000 cubic yards of the suspended sediment observations may be fortuitous. It does suggest, however, that the quantities developed for conditions with the proposed improvements in place are probably reasonable.

CHAPTER VII - STANDARD PROJECT FLOOD

25. INTRODUCTION

In general, the "standard project flood" (SPF) is defined as an estimate of flood discharges that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the basin. In this study, the standard project flood was developed to serve as a basis for aid in extrapolating flood discharge-frequency curves and to establish the percentage of the SPF that can be conveyed by the leveed floodway of Red River. Further, the correlated isohyetal patterns and discharge relations necessary for computing the SPF will serve as a basis for reservoir regulation studies likely to be needed in the future. The following paragraphs describe the procedures used to select the standard project storm (SPS) series; compute the rainfall excess (runoff) within the basin; and route unregulated and regulated flood discharges; and include a discussion of the adequacy of the presently approved interim and ultimate levee grades to convey, under present channel conditions, the SPF regulated by all authorized reservoirs.

26. STORM STUDIES AND STORM TRANSPOSITION

a. The SPS for the basin was developed from data contained in the U. S. Army Corps of Engineers publication "Storm Rainfall in the United States, Depth-Area-Duration Data" dated 1945, generally as outlined in the U. S. Army Corps of Engineers EM 1110-2-1411 (Civil Works Bulletin No. 52-8, pages 13 through 16). In view of the size and general hydrologic characteristics of the basin, relatively long periods of rainfall or series of rainfall events are required to produce critical flood discharges along the lower reaches of Red River. A review of flood records of Red River, and consideration of general meteorological characteristics that govern major flood-producing storms in the project area, led to the conclusion that at least two major storm events should be included in the hypothetical SPS series. Thirty-four storms, with centers located in or adjacent to the basin, were considered in selecting the SPS series. The storm combination selected was composed of two storms of actual occurrence, 6-10 May 1943 and 15-20 May 1943, which are designated as SW 2-20 and SW 2-21, respectively, in the publication first referenced above. The first storm, SW 2-20, was assumed to occur on the same dates as the actual storm; the second sequence was assumed to occur 2 days earlier than the actual occurrence or on 13-18 May. The above sequence produces the most severe rainfall that can be considered reasonably characteristic of the region. Further advancing the dates of occurrence of the second storm would produce higher peak discharges along the lower reaches of the river; analysis of available data indicate, however, that the series thus produced would be anomalous to the region.

b. Each storm was transposed from its original position to a position over the basin and its axis rotated to produce a critical runoff condition on the river at and below Fulton, Arkansas. The center of the first storm was moved from Warner, Oklahoma, and placed over Fort Towson, Oklahoma, between Fulton and Denison Dam, and the isohyetal pattern was rotated 7 degrees clockwise (see figure 19). The second storm center was transposed from Lowell, Kansas, and placed over Minden, Louisiana, in the basin between Fulton and Alexandria and the isohyetal pattern was rotated clockwise 35 degrees (see figure 20). Since both storms were transposed to different locations, consideration was given to adjustments in rainfall based on geographical relocation, seasonal variation, and maximization effects. The adjustments adopted were 90 percent and 109 percent for SW 2-20 and SW 2-21, respectively (see table 20). These locations and adjustments to rainfall amounts resulted in critical coincidence of the two storms.

27. DETERMINATION OF STORM RUNOFF

a. Each isohyetal pattern, including the rainfall gaging stations with its associated Thiessen polygons, was overlayed and reconstructed at its assigned position in the basin. Figures 21 through 24 show the reconstructed isohyetal pattern in the upper and lower portions of the basin for the transposed storms. The procedure used to compute rainfall-excess is illustrated for a small subbasin in table 21 and described below. Rainfall stations were grouped under the subbasin in which a portion of its Thiessen polygons fell and were tabulated in columns 2 (drainage basin) and 3 (precipitation station). Each area (A_p, Col. 4), represented by a rainfall gaging station was computed by planimetering that portion of the station Thiessen polygon within the subbasin. Station rainfalls (P_{sta}) were tabulated in column 5. The area average rainfalls (P_{av}, Col. 6) were obtained by dividing the area (A_p) into parts bounded by isohyets, and planimetering and weighting these parts to obtain the average.

b. Using the values of A_p, P_{sta}, and P_{av}, the values for $P_{av} \div P_{sta}$ and conversion factor F_c ($=A_p \times P_{av} \div P_{sta}$) were computed. F_c was then multiplied by the appropriate transposition factor for the selected storm [i.e., for the transposed storm SW 2-20, F_c was multiplied by 0.90 to obtain the SPS (F_c) value; likewise, the F_c applicable to SW 2-21 was multiplied by 1.09 to obtain SPS (F_c)]. These values of $P_{av} \div P_{sta}$ and SPS (F_c) were entered into columns 7 and 8, respectively.

c. The weighted depth-area amount (volume of rainfall) for each 6-hour rainfall period was computed for all rainfall gaging station areas. Data from mass rainfall curves for each storm and the conversion factors (F_c) previously computed and entered in column 8 were used in this computation. The volumes of rainfall

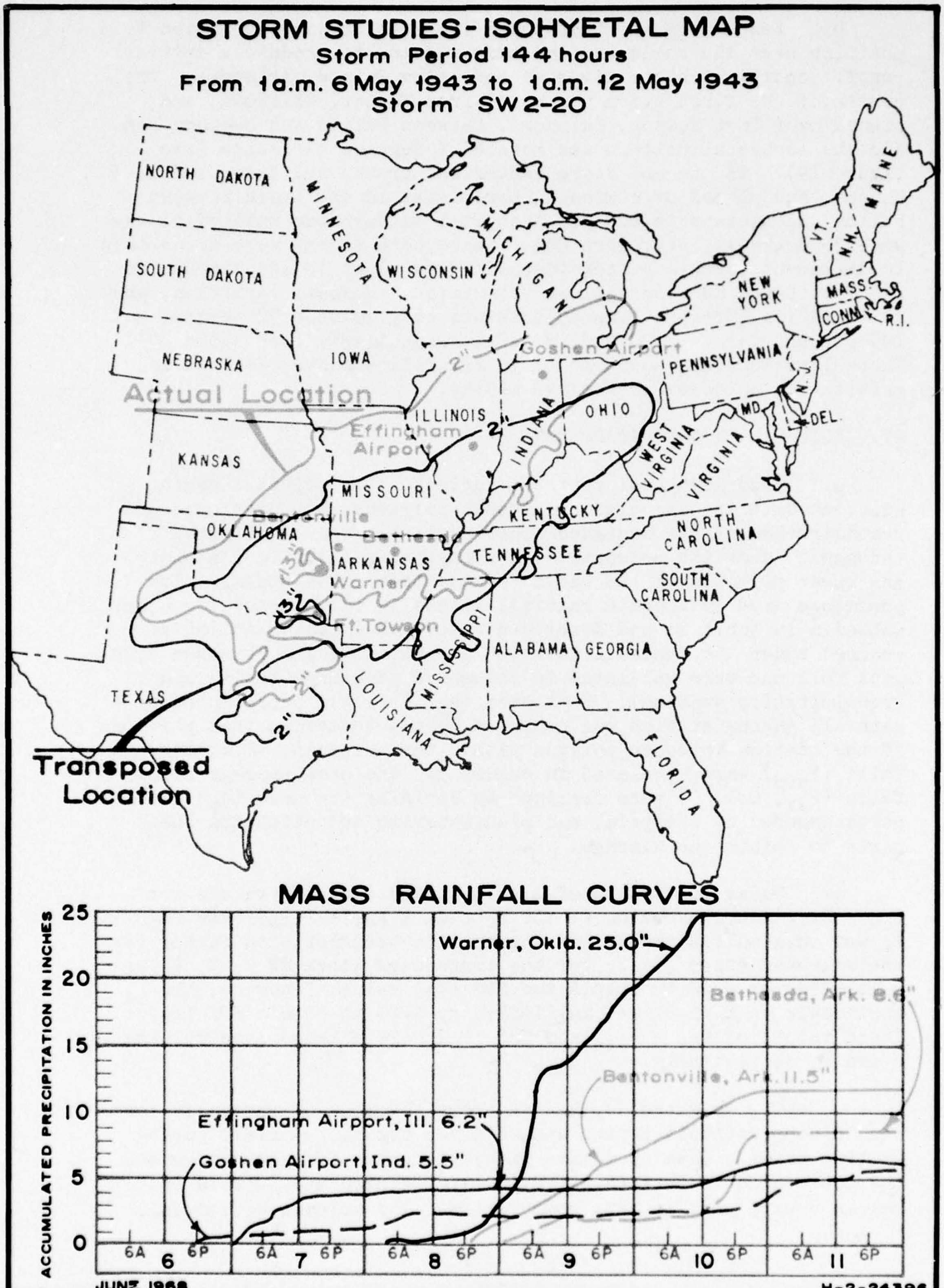
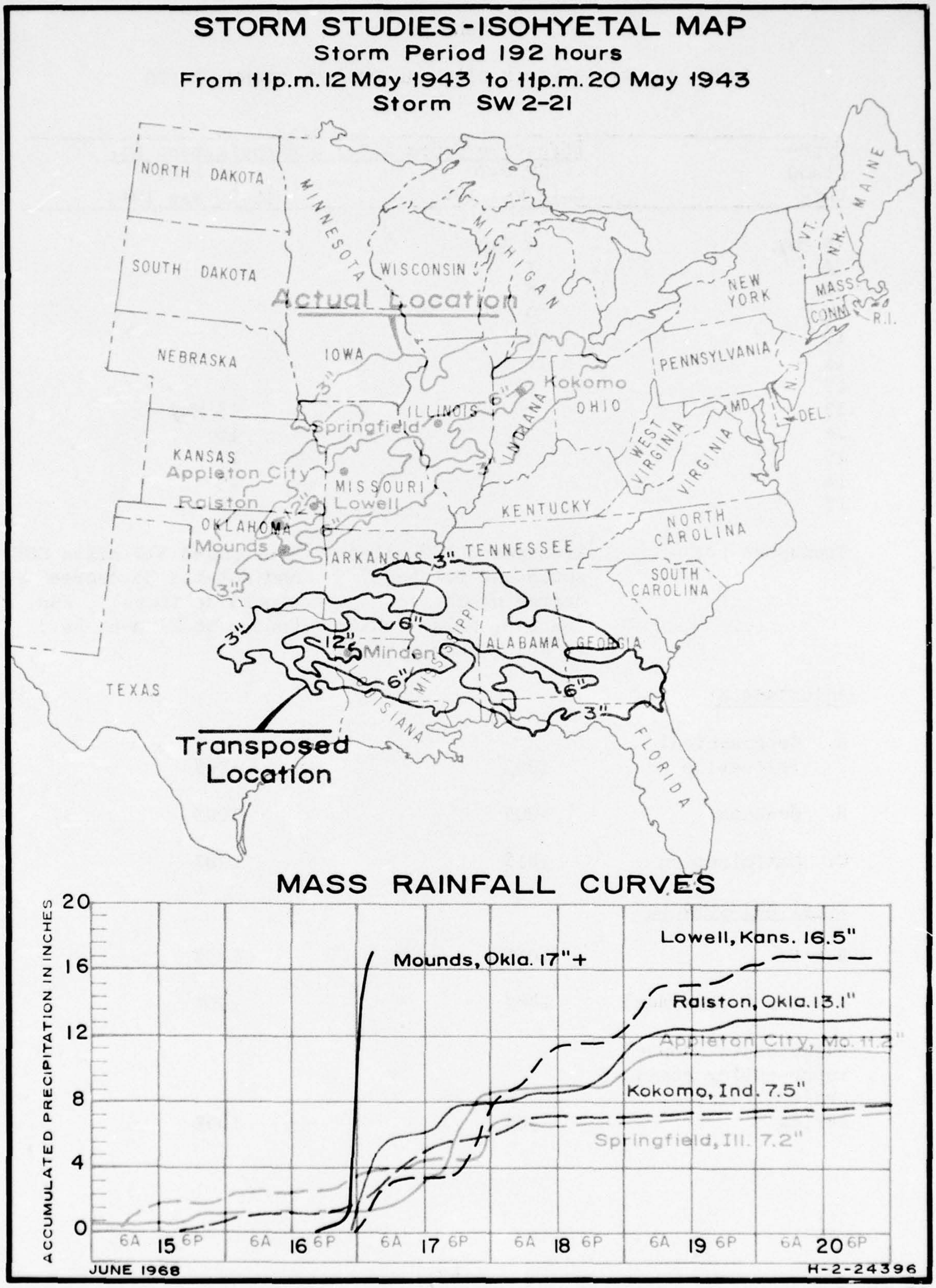

STORM STUDIES-ISOHYETAL MAP
Storm Period 144 hours
From 1a.m. 6 May 1943 to 1a.m. 12 May 1943
Storm SW2-20
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
MD.
DEL.
N.J.
CONN.
MASS
R.I.
VT.
N.H.
MAINE
Actual Location
Transposed Location
Goshen Airport
Effingham Airport
Bentonville
Bethesda
Warner
Ft. Towson
MASS RAINFALL CURVES
ACCUMULATED PRECIPITATION IN INCHES
Warner, Okla. 25.0"
Bethesda, Ark. 8.6"
Bentonville, Ark. 11.5"
Effingham Airport, Ill. 6.2"
Goshen Airport, Ind. 5.5"
JUNE 1968
H-2-24396

FIGURE 19



STORM STUDIES - ISOHYETAL MAP
Storm Period 192 hours
From 11p.m. 12 May 1943 to 11p.m. 20 May 1943
Storm SW 2-21
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MISSISSIPPI
MICHIGAN
INDIANA
KENTUCKY
TENNESSEE
ALABAMA
GEORGIA
FLORIDA
OHIO
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
PENNSYLVANIA
NEW YORK
MD.
DEL.
N.J.
VT.
N.H.
MAINE
MASS
CONN
R.I.
Actual Location
Transposed Location
Kokomo
Springfield
Appleton City
Lowell
Ralston
Mounds
Minden
3"
6"
12"
MASS RAINFALL CURVES
ACCUMULATED PRECIPITATION IN INCHES
20
16
12
8
4
0
Mounds, Okla. 17"+
Lowell, Kans. 16.5"
Ralston, Okla. 13.1"
Appleton City, Mo. 11.2"
Kokomo, Ind. 7.5"
Springfield, Ill. 7.2"
6A 15 6P
6A 16 6P
6A 17 6P
6A 18 6P
6A 19 6P
6A 20 6P
JUNE 1968
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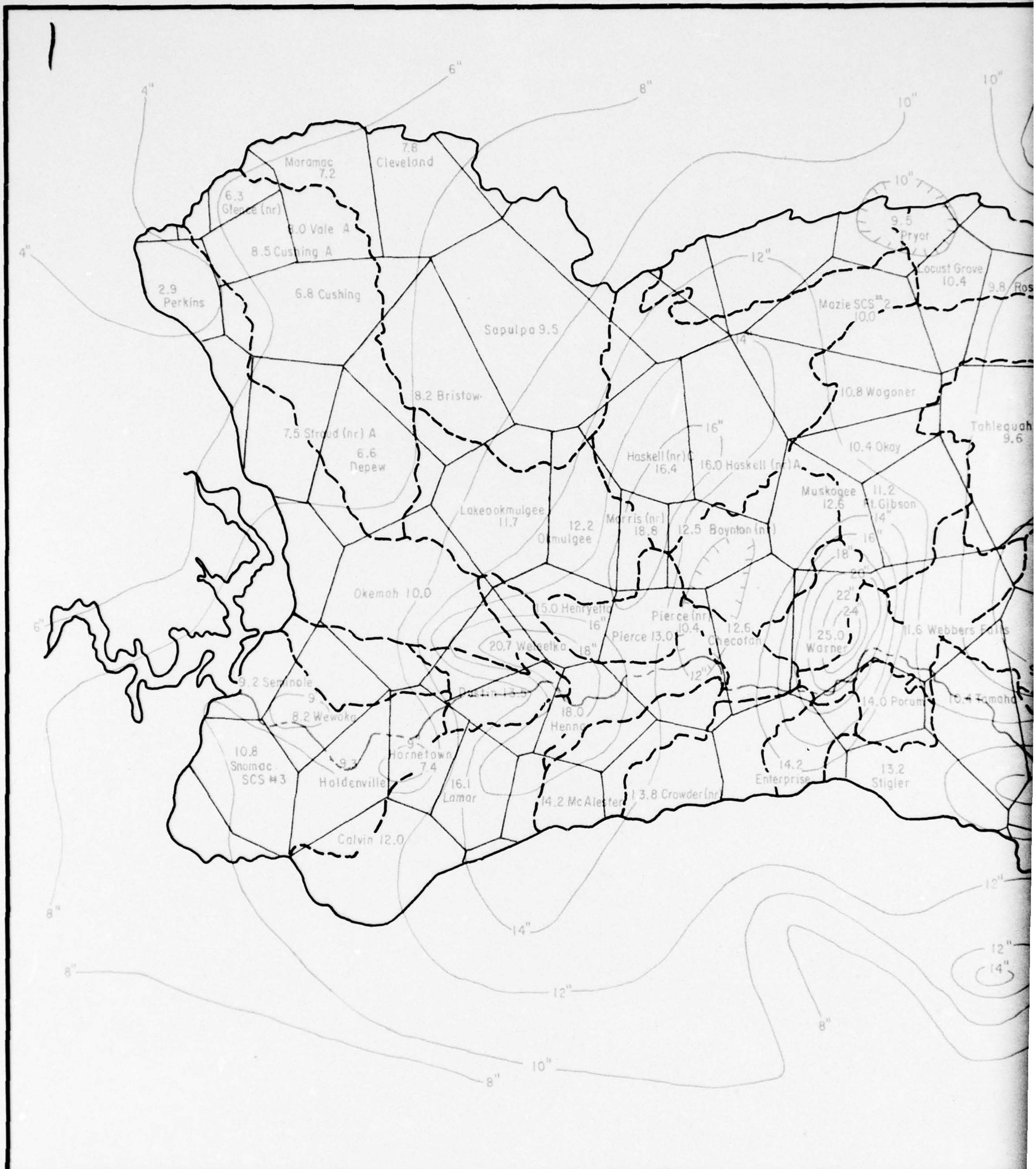
FIGURE 20

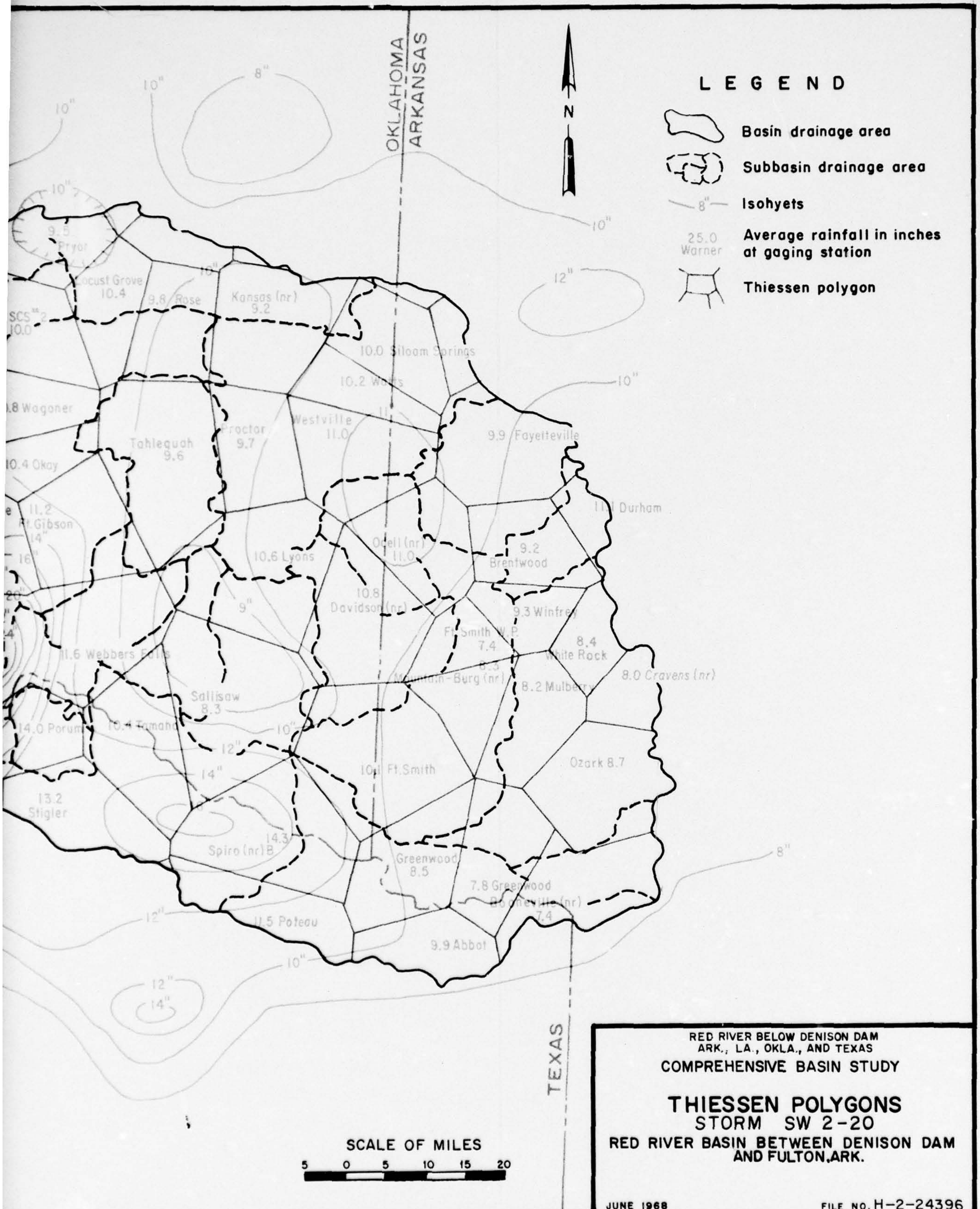
TABLE 20

LOWER RED RIVER BASIN STANDARD PROJECT STORM SERIES

Hypo-Flood Date	Effective Storm Dates and Assignment No.	
	SW 2-20 6-12 May 1943	SW 2-21 15-20 May 1943
6 May	6 May	
7	7	
8	8	
9	9	
10	10	
11	11	
12		
13		15 May
14		16
15		17
16		18
17		19
Transpose to:	Transposed 100 miles south and rotated 7 degree clockwise. (Warner, Okla. Center to Ft. Towson, Okla.)	Transposed 310 miles SSE and rotated 35 degree clockwise (Lowell, Kan. Center to Minden, La.)
Adjustments:		
A. Geographical relocation	105%	109%
B. Seasonal	100%	100%
C. Maximization	141%	128%
Total Adjustments		
A x B	105%	109%
A x B x C (Maximum)	148%	139%
Adjustments adopted representing standard project rainfall series	90%	109%


1
Maramac 7.2
7.8 Cleveland
6.3 Glencoe (nr)
8.0 Vale A
8.5 Cushing A
2.9 Perkins
6.8 Cushing
Sapulpa 9.5
8.2 Bristow
7.5 Stroud (nr) A
6.6 Depew
Lakeookmulgee 11.7
12.2 Okmulgee
Okemah 10.0
15.0 Henryetta
20.7 Weleetka
9.2 Seminole
8.2 Wewoka
Dustin 13.5
18.0 Henryetta
10.8 Snomac SCS #3
Holdenville
Hornetown 7.4
16.1 Lamar
Calvin 12.0
14.2 McAlester
13.8 Crowder (nr)
Haskell (nr) C 16.4
16.0 Haskell (nr) A
Morris (nr) 18.8
12.5 Boynton (nr)
Pierce (nr) 10.4
Pierce 13.0
12.6 Checotah
25.0 Warner
14.2 Enterprise
13.2 Stigler
14.0 Porum
10.4 Tamaha
11.6 Webbers Falls
Muskogee 12.6
11.2 Ft. Gibson
10.4 Okay
10.8 Wagoner
Tahlequah 9.6
Mazie SCS #2 10.0
Locust Grove 10.4
9.8 Ros
9.5 Pryor
4"
6"
8"
10"
12"
14"
16"
18"
20"
22"
24"

2



RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

THIESSEN POLYGONS
STORM SW 2-20
RED RIVER BASIN BETWEEN DENISON DAM AND FULTON, ARK.

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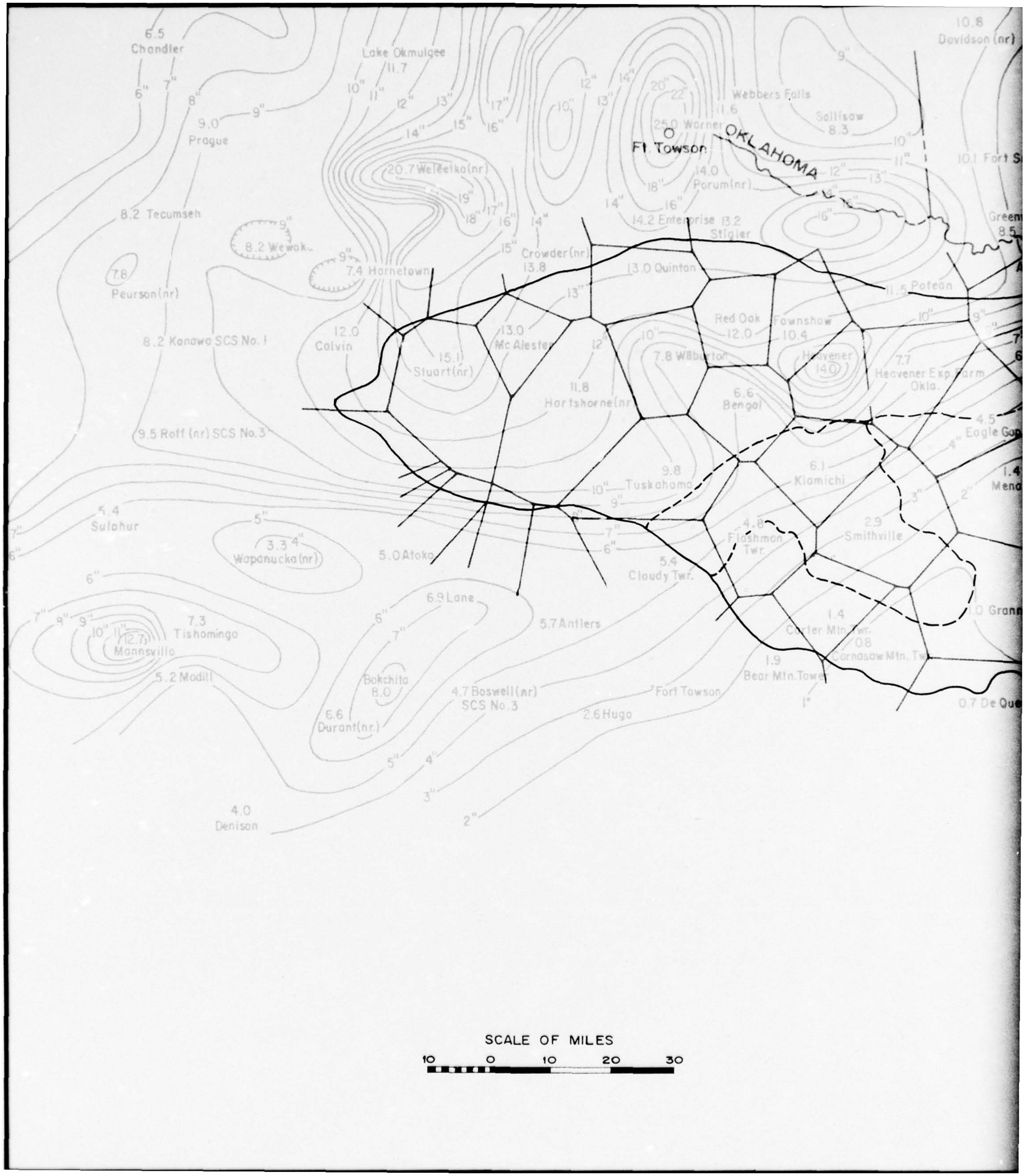
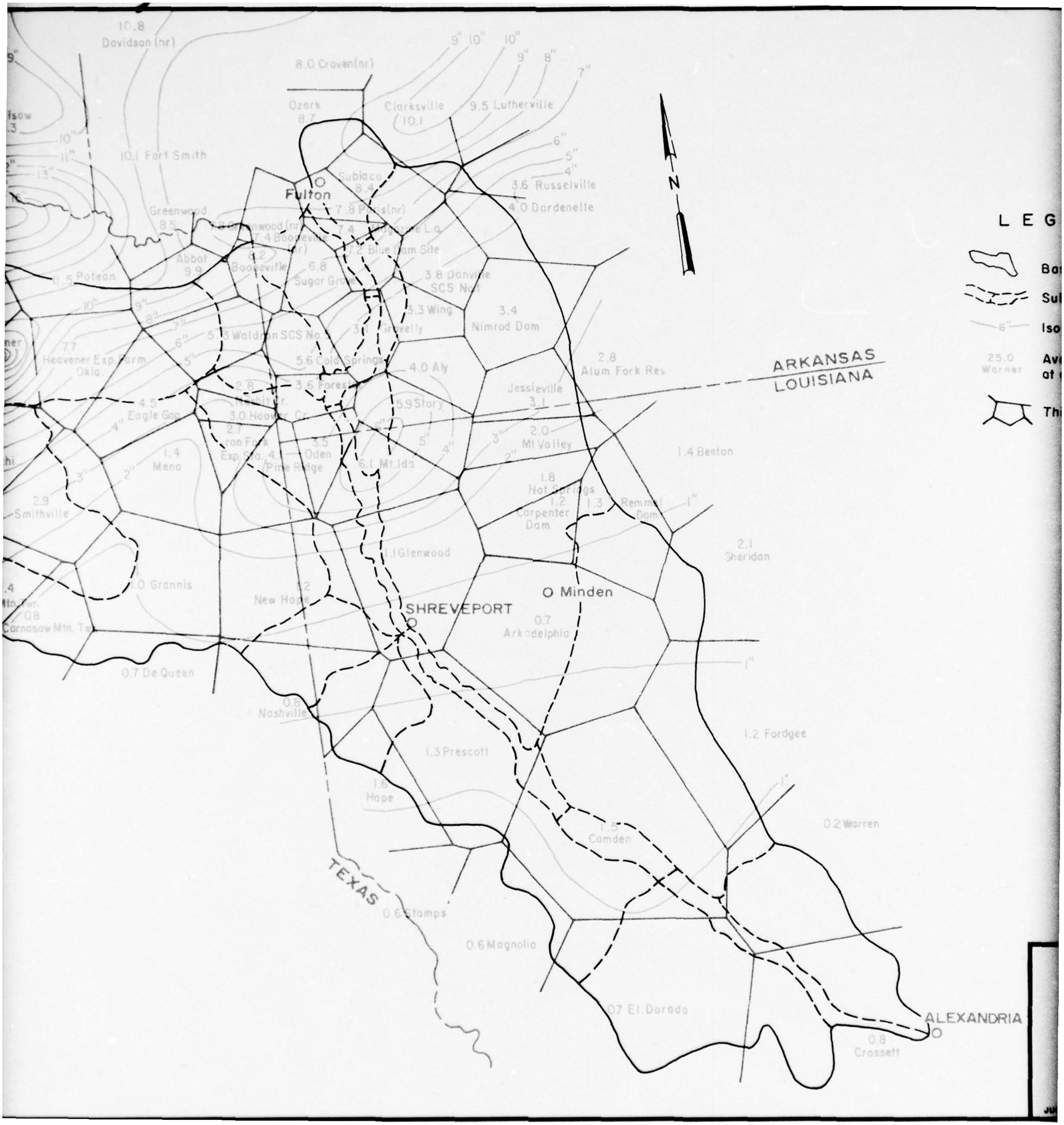
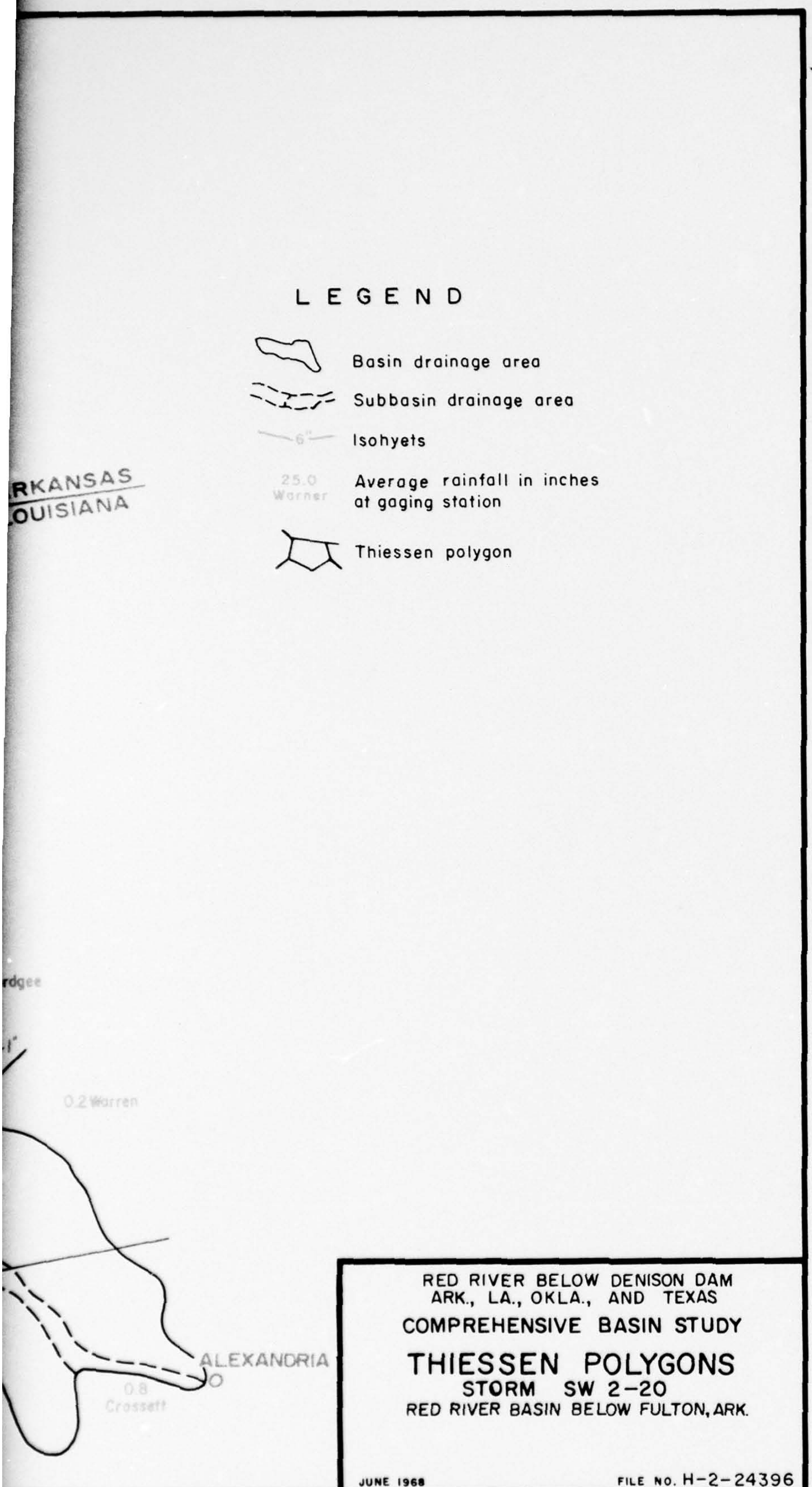
FIGURE 21



6.5 Chandler
Lake Okmulgee 11.7
9.0 Prague
20.7 Weleetka (nr)
8.2 Tecumseh
8.2 Wewoka
7.4 Hornetown
7.8 Pearson (nr)
8.2 Konawa SCS No. 1
12.0 Calvin
15.1 Stuart (nr)
13.0 McAlester
Crowder (nr) 13.8
13.0 Quinton
14.2 Enterprise
13.2 Stigler
25.0 Warner
Ft. Towson
OKLAHOMA
Webbers Falls 11.6
Sallisaw 8.3
14.0 Porum (nr)
10.8 Davidson (nr)
10.1 Fort S
11.5 Poteau
Red Oak 12.0
Fanshaw 10.4
7.8 Wilburton
Heavener 14.0
7.7 Heavener Exp. Farm Okla.
11.8 Hartshorne (nr)
6.6 Bengal
4.5 Eagle Gap
9.5 Roff (nr) SCS No. 3
9.8 Tuskahoma
6.1 Kiamichi
5.4 Sulphur
3.3 Wapanucka (nr)
5.0 Atoka
4.8 Flashman Twr.
2.9 Smithville
5.4 Cloudy Twr.
6.9 Lane
5.7 Antlers
1.4 Carter Mtn. Twr.
0.8 Carnasaw Mtn. Tw
7.3 Tishomingo
12.7 Mannsville
5.2 Madill
Bokchito 8.0
4.7 Boswell (nr) SCS No. 3
Fort Towson
1.9 Bear Mtn. Tower
6.6 Durant (nr)
2.6 Hugo
4.0 Denison
1.0 Grann
0.7 De Que
SCALE OF MILES
10 0 10 20 30



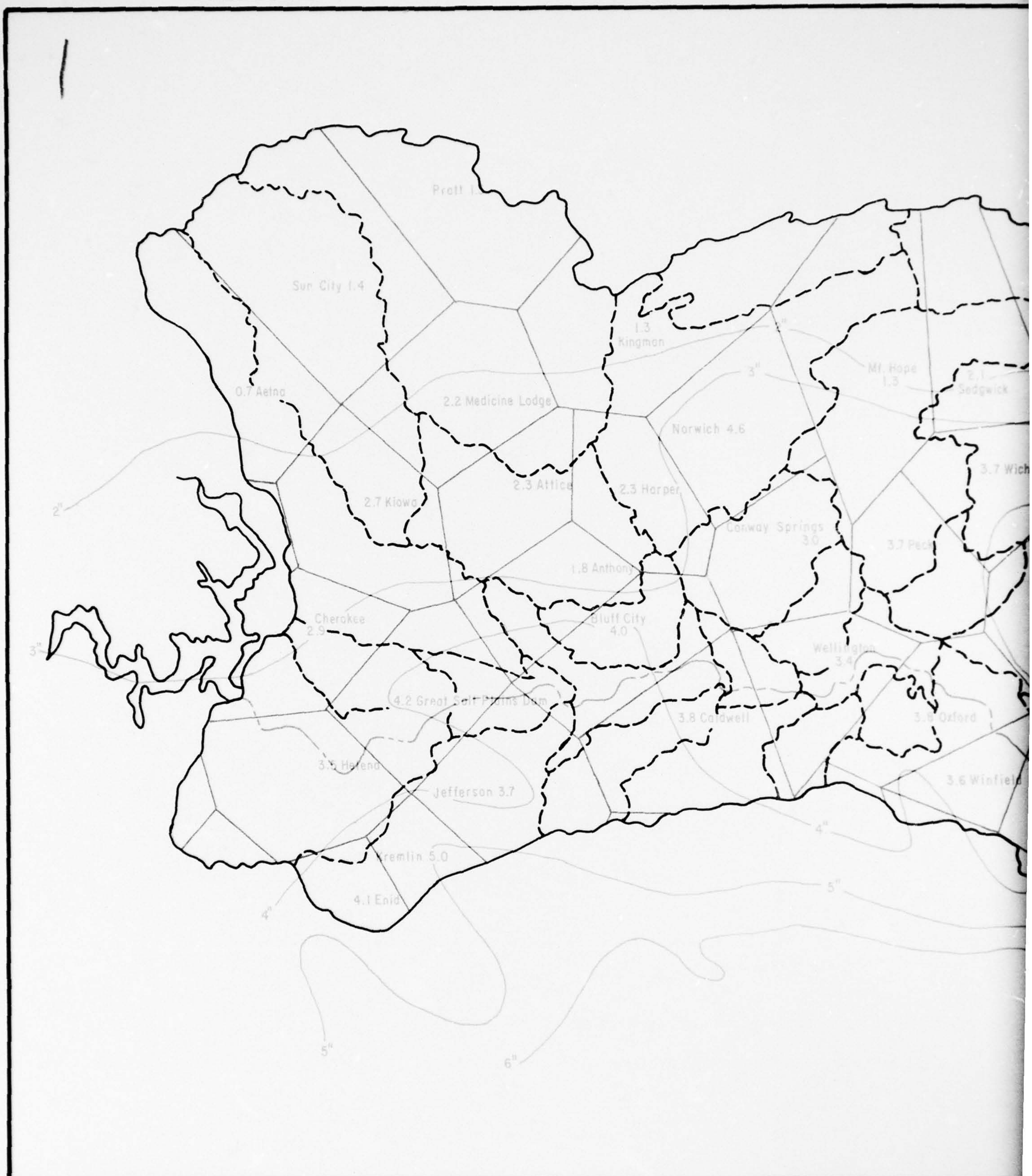
10.8
Davidson (nr)
8.0 Craven (nr)
Ozark
8.7
Clarksville
10.1
9.5 Lutherville
10.1 Fort Smith
Fulton
Subiaco
8.4
3.6 Russelville
4.0 Dardenelle
7.8 Paris (nr)
Greenwood
8.5
7.4 Booneville
Abbot
9.9
11.5 Potean
Booneville
6.8
Sugar Grove
7.2 Blue Dam Site
3.8 Danville
SCS No.1
3.3 Wing
3.4
Nimrod Dam
Gravelly
7.7
Heavener Exp. Farm
Okla.
5.6 Cold Springs
4.0 Aly
2.8
Alum Fork Res
ARKANSAS
LOUISIANA
3.6 Forester
Jessieville
3.1
4.5
Eagle Gap
3.0 Hoover Cr.
5.9 Story
2.7
Iron Fork
Exp. Sta.
3.5
Oden
4.1
Pine Ridge
2.0
Mt Valley
1.4 Benton
1.4
Mena
6.1 Mt. Ida
1.8
Hot Springs
1.2
Carpenter
Dam
1.3
Remmel
Dam
2.9
Smithville
1.1 Glenwood
2.1
Sheridan
1.0 Grannis
New Hope
O Minden
SHREVEPORT
0.8
Carnosaw Mtn. Tw.
0.7
Arkadelphia
0.7 De Queen
0.8
Nashville
1.2 Fordgee
1.3 Prescott
1.6
Hope
0.2 Warren
1.5
Camden
TEXAS
0.6 Stamps
0.6 Magnolia
0.7 El. Dorado
ALEXANDRIA
0.8
Crossett
N



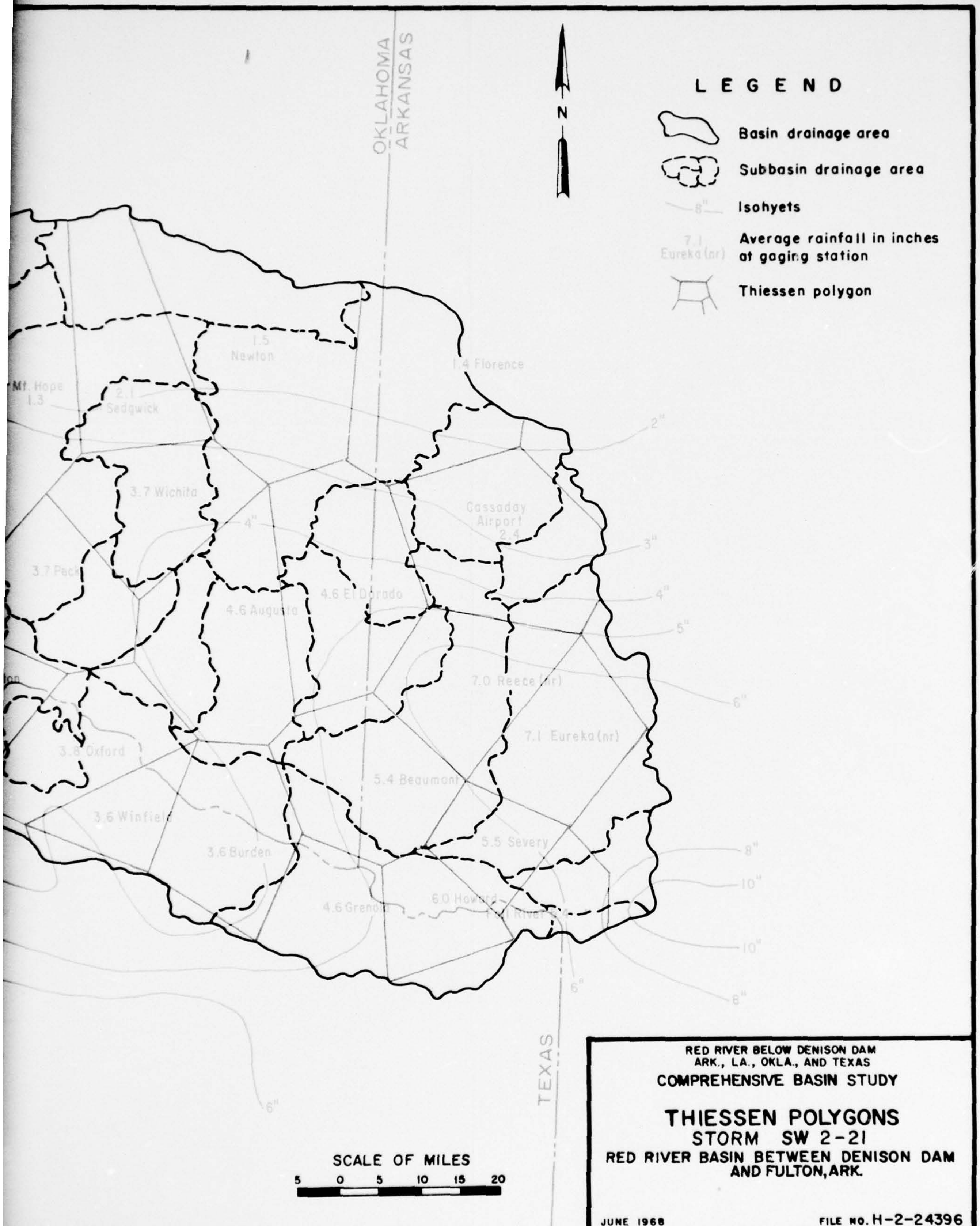
RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY
THIESSEN POLYGONS
STORM SW 2-20
RED RIVER BASIN BELOW FULTON, ARK.

JUNE 1968 FILE NO. H-2-24396

FIGURE 22


Sun City 1.4
1.3 Kingman
Mt. Hope 1.3
Sedgwick
0.7 Aetna
2.2 Medicine Lodge
Norwich 4.6
2.3 Attica
2.3 Harper
2.7 Kiowa
Conway Springs 3.0
1.8 Anthony
Cherokee 2.9
Bluff City 4.0
Wellington 3.4
4.2 Great Salt Plains Dam
3.8 Caldwell
3.6 Oxford
3.5 Helena
Jefferson 3.7
Kremlin 5.0
4.1 Enid
2"
3"
4"
5"
6"

2

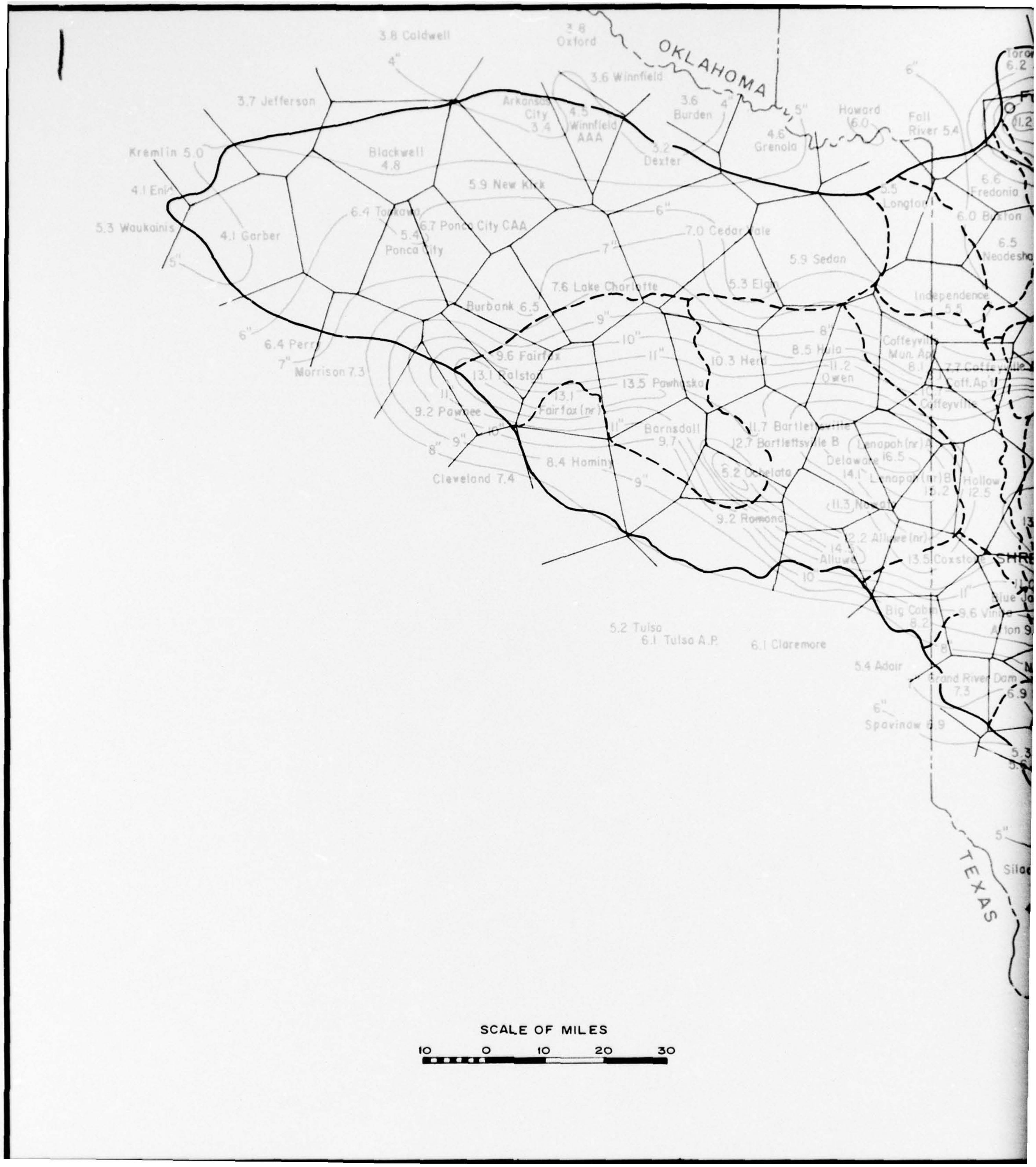


RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

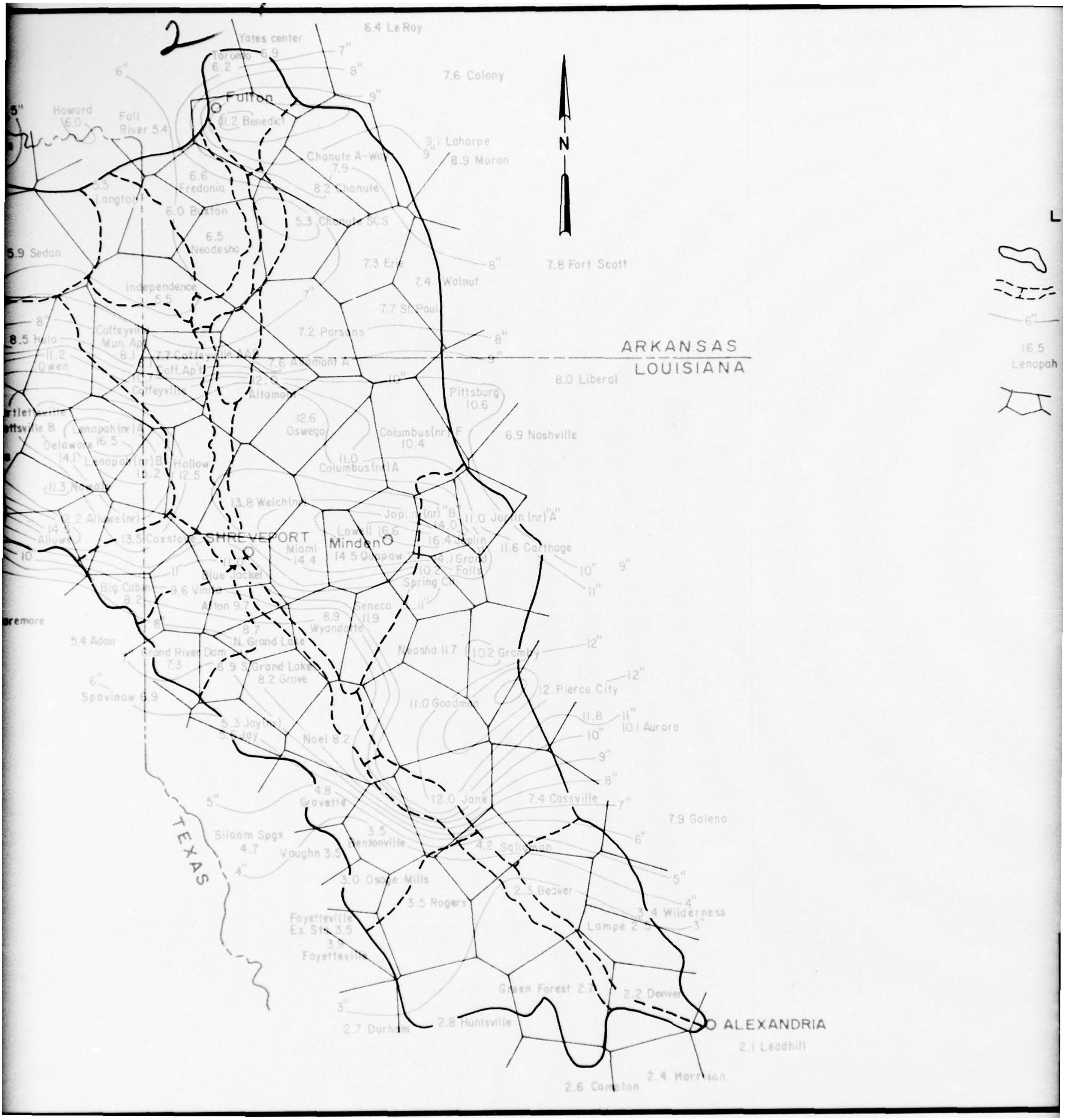
THIESSEN POLYGONS
STORM SW 2-21
RED RIVER BASIN BETWEEN DENISON DAM AND FULTON, ARK.

JUNE 1968 FILE NO. H-2-24396

FIGURE 23



OKLAHOMA
TEXAS
3.8 Caldwell
3.8 Oxford
3.6 Winnfield
3.7 Jefferson
Arkansas City 3.4
4.5 Winnfield AAA
3.6 Burden
3.2 Dexter
4.6 Grenola
Howard 6.0
Fall River 5.4
Kremlin 5.0
Blackwell 4.8
4.1 Enid
5.9 New Kirk
6.6 Fredonia
5.5 Longton
6.0 Buxton
5.3 Waukomis
4.1 Garber
6.4 Tonkawa
6.7 Ponca City CAA
5.4 Ponca City
7.0 Cedar Vale
5.9 Sedan
6.5 Neodesha
7.6 Lake Charlotte
5.3 Elgin
Independence 5.5
Burbank 6.5
6.4 Perry
Morrison 7.3
9.6 Fairfax
13.1 Ralston
10.3 Herd
8.5 Hula
11.2 Owen
Coffeyville Mun. Ap. 8.1
7.7 Coffeyville
13.5 Pawhuska
13.1 Fairfax (nr)
9.2 Pawnee
Barnsdall 9.7
11.7 Bartlettsville
12.7 Bartlettsville B
Lenapah (nr) A 16.5
Delaware 14.1
8.4 Hominy
Cleveland 7.4
Lenapah (nr) B
Hollow 12.5
11.3 Nowata
9.2 Romona
Alluwe
13.5 Coxstone
Big Cabin 8.2
9.6 Vinita
5.2 Tulsa
6.1 Tulsa A.P.
6.1 Claremore
5.4 Adair
Grand River Dam 7.3
Spavinaw 6.9
SCALE OF MILES
10 0 10 20 30



2
6.4 Le Roy
Yates center
Toronto 6.9
6.2
7.6 Colony
Fulton
Howard
6.0
Fall
River 5.4
11.2 Benedict
9.1 Laharpe
8.9 Moran
Chanute A-W
7.9
8.2 Chanute
6.6
Fredonia
5.5
Longton
6.0 Buxton
5.3 Chanute SCS
6.5
Neodesha
5.9 Sedan
7.3 Erie
7.8 Fort Scott
7.4 Walnut
Independence
5.5
7.7 St. Paul
8.5 Hula
Coffeyville
Mun. Ap.
8.1
7.2 Parsons
11.2
Owen
7.7 Coffeyville AAF
Coff. Ap't
7.6 Altamont A
12.0
Altamont
ARKANSAS
LOUISIANA
8.0 Liberal
Coffeyville
Pittsburg
10.6
12.6
Oswego
Columbus (nr) F
10.4
6.9 Nashville
Lenapah (nr) A
16.5
Delaware
14.1
Lenapah (nr) B
15.2
Hallow
12.5
11.0
Columbus (nr) A
11.3 Nowata
13.8 Welch (nr)
Joplin (nr) "B"
14.0
11.0 Joplin (nr) "A"
12.2 Alluwe (nr)
14.5
Alluwe
13.5 Coxstone
SHREVEPORT
Miami
14.4
Minden
Lowell 16.6
16.4 Joplin
14.5 Quapaw
14.1 Grand Falls
11.6 Carthage
10.2
Spring City
Blue Jacket
Big Cabin
8.2
9.6 Vinita
Afton 9.7
Seneca
11.9
8.9
Wyandotte
8.7
N. Grand Lake
5.4 Adair
Grand River Dam
7.3
Neosho 11.7
10.2 Granby
5.9 S. Grand Lake
8.2 Grove
12. Pierce City
Spavinaw 5.9
11.0 Goodman
11.8
10.1 Aurora
5.3 Jay (nr)
5.8 Jay
Noel 8.2
4.8
Grovette
12.0 Jane
7.4 Cassville
7.9 Galena
TEXAS
Siloam Spgs
4.7
3.5
Bentonville
Vaughn 3.5
4.2 Saligman
3.0 Osage Mills
2.3 Beaver
3.5 Rogers
3.4 Wilderness
Fayetteville
Ex. Sta. 3.5
Lampe 2.5
3.9
Fayetteville
Green Forest 2.7
2.2 Denver
2.7 Durham
2.8 Huntsville
ALEXANDRIA
2.1 Leadhill
2.4 Harrison
2.6 Compton
16.5
Lenapah

LEGEND

Basin drainage area

Subbasin drainage area

6" Isohyets

16.5
Lenapah Average rainfall in inches at gaging station

Thiessen polygon

ANDRIA
eadhill

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

THIESSEN POLYGONS
STORM SW 2-21
RED RIVER BASIN BELOW FULTON, ARK.

JUNE 1968 FILE NO. H-2-24396

DEFINITIONS:
A_p=AREA WITHIN STATION-POLYGON AND BASIN.
P_{sta}=TOTAL RAINFALL AT OBSERVATION STATION.
P_{av}=AVERAGE DEPTH RAINFALL WITHIN AREA A_p.
INITIAL LOSS=INFILTRATION REQUIRED BEFORE RAINFALL-EXCESS BEGINS

TABLE 21 - COMPUTATION OF INFILTRATION INDICES

RED RIVER BASIN BELOW DENISON DAM, SUBBASIN No. 10, FERRELLS BRIDGE RESERVOIR

STORM PERIOD: 1943 6-12 May
144 HOURS FROM 1:00 A. M. 6 May
TO 1:00 A. M. 12 May

PART I - RAINFALL VOLUMES

VOLUME OF RAINFALL WITHIN AREA A_p, IN INCH - SQ. MI. (EQUALS F_c X 6 - HOUR RAINFALL INCREMENTS) — TIME AT END OF 6 - HOUR PERIODS

LINE	DRAINAGE BASIN	PRECIPITATION STATION	A_p IN SQ.MI.	P_{sta} IN INCHES	P_{av} IN INCHES	P_{av}/P_{sta}	F_{cw} $A_p(P_{av}/P_{sta})$	12M5	6A6	12N6	6P6	12M6	6A7	12N7	6P7	12M7	6A8	12N8	6P8	12M8	6A9	12N9	6P9	12M9	6A10	12N10	6P10	12M10	6A11	12N11	6P11	TOTAL
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	Subbasin No.10	Cloudy Tower	57	5.4	5.8	1.07	55	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	60	99	121	11	0	0	0	0	297
2	Ferrells	Tuskahoma	46	9.8	7.6	0.78	32	0	0	0	0	0	0	0	0	0	0	0	0	3	0	19	42	6	208	32	4	0	0	0	0	314
3	Bridge	Bengal	11	6.6	6.7	1.02	10	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0	13	10	30	3	1	0	0	0	0	66
4	Reservoir	Flashman Twr.	145	4.8	5.6	1.17	153	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	-0	184	76	459	0	0	0	0	0	734
5		Kiamichi Twr.	210	6.1	6.0	0.98	185	0	0	0	0	37	0	0	0	0	19	0	0	55	0	0	148	148	0	721	0	0	0	0	0	1128
6		Smithville	226	2.9	2.7	0.93	189	0	0	0	0	0	0	0	38	0	0	0	38	0	0	0	0	0	0	0	453	0	0	0	19	548
7		Grannis	95	1.0	0.9	0.90	77	0	0	0	0	0	0	0	4	0	0	1	5	0	0	8	15	15	8	15	6	0	0	0	0	77
8		Carnasaw Mtn. Twr.	17	0.8	1.0	1.25	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	6	5	15
9		Carter Mtn. Twr.	43	1.4	2.0	1.43	55	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	4	0	0	22	29	77
10																																
11		Subtotal	850		4.26		775	0	0	0	15	37	0	0	64	0	19	7	43	66	1	27	221	423	421	1351	480	0	0	28	53	3256
12																																
13		Inches Rainfall						0	0	0	0.02	0.04	0	0	0.07	0	0.02	0.01	0.05	0.08	0	0.03	0.26	0.50	0.50	1.59	0.56	0	0	0.03	0.06	3.83
14																																
15																																
16																																
17																																

PART II - RAINFALL - EXCESS VOLUMES

VOLUME OF RAINFALL - EXCESS WITHIN AREA A_p, CORRESPONDING TO F_{av}, IN INCH - SQUARE MILES — TIME AT END OF 6 - HOUR PERIODS

LINE	DRAINAGE BASIN	PRECIPITATION STATION	A_p IN SQ.MI.	INITIAL LOSS INCHES	INITIAL LOSS INCH-SQ.MI.	F_{av} IN./HR.	F_{av} IN.-MI. PER 6 HRS.	12M5	6A6	12N6	6P6	12M6	6A7	12N7	6P7	12M7	6A8	12N8	6P8	12M8	6A9	12N9	6P9	12M9	6A10	12N10	6P10	12M10	6A11	12N11	6P11	TOTAL
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
18	Subbasin No.10	Cloudy Tower	57	0.55	31	0.044	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	84	106	0	0	0	0	0	207
19	Ferrells	Tuskahoma	46	0.55	25	0.044	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	196	20	0	0	0	0	0	245
20	Bridge	Bengal	11	0.55	6	0.044	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	7	27	0	0	0	0	0	0	44
21	Reservoir	Flashman Twr.	145	0.55	80	0.044	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	38	421	0	0	0	0	0	525
22		Kiamichi Twr.	210	0.55	116	0.044	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	104	93	0	666	0	0	0	0	0	863
23		Smithville	226	0.55	124	0.044	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	345	0	0	0	0	345
24		Grannis	95	0.55	52	0.044	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25		Carnasaw Mtn. Twr.	17	0.55	9	0.044	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
26		Carter Mtn. Twr.	43	0.55	24	0.044	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	18	29
27																																
28		Subtotal	850					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	183	345	1213	345	0	0	11	19	2259
29																																
30		Inches Runoff						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0.22	0.41	1.43	0.41	0	0	0.01	0.02	2.66
31																																
32																																
33																																
34																																

REMARKS: The center of this storm, SW 2-20, was located at Warner, Okla. For use in computing the standard project flood (SPF), the storm was rotated 7 degrees clockwise and the center moved 100 miles south to Fort Towson, Okla.

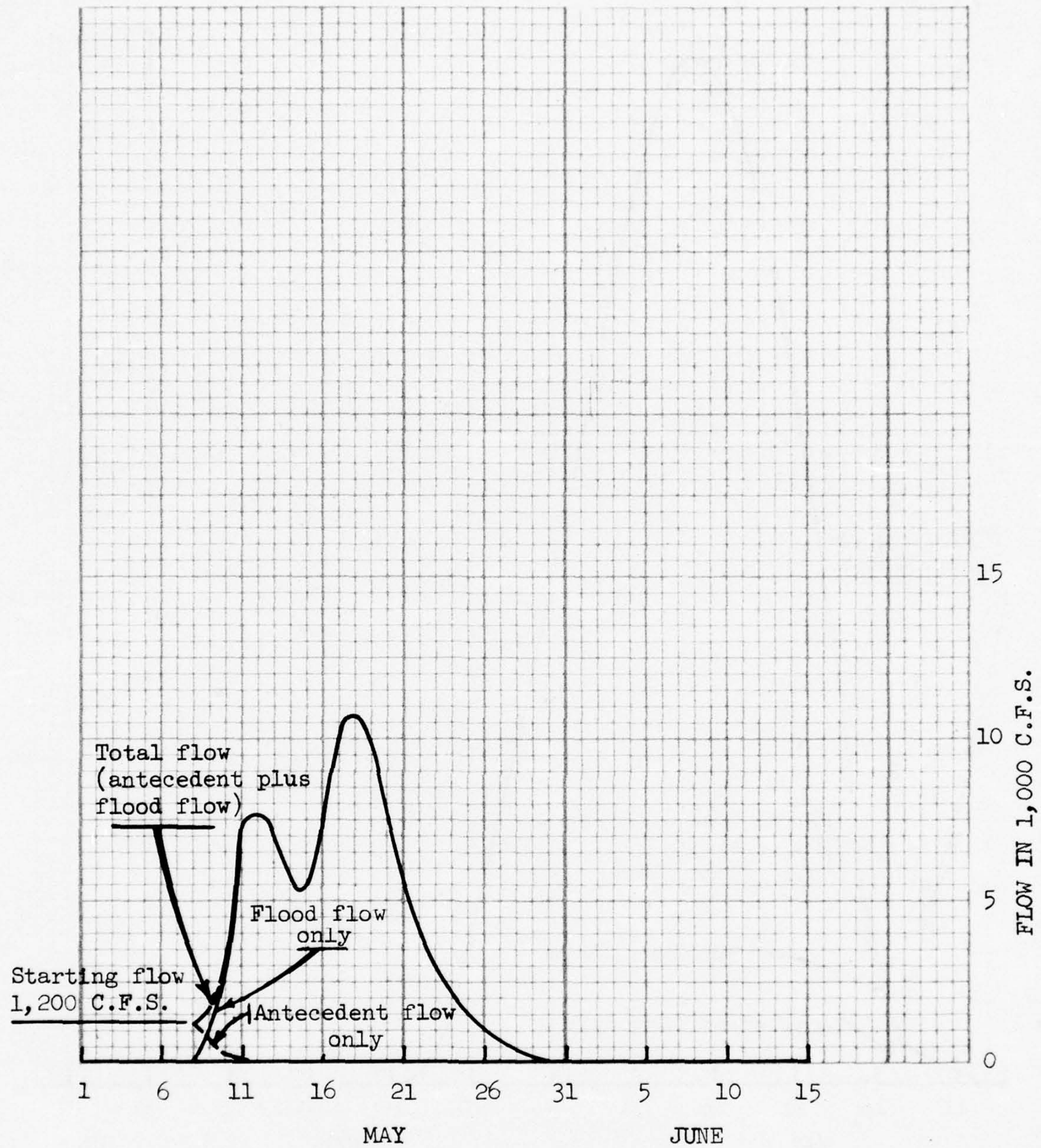
were recorded in columns 9 through 32 and each column was summed to show the total rainfall over the subbasin for that particular time period. The dates and times of occurrence are shown in the heading above the rainfall amounts.

d. The infiltration values (F_{av}) derived from a hydrologic analysis of Red River were entered into column 7 of part II. The initial loss values shown in the table were determined from the backup data for the Interim Report with consideration given to the season of the year and the antecedent moisture conditions. These values were recorded in column 5, part II of the form.

e. Rainfall-excess (runoff) values were then computed for all the subbasins involved, generally as illustrated in table 21 and on plate 4 of the Corps of Engineers EM 1110-2-1405. The results were converted to inches of runoff for each 6-hour period over each subbasin.

f. The rainfall-excess values for each subbasin, determined as outlined above, were used along with the unit hydrographs to compute hypothetical flood hydrograph for each subbasin. The unit hydrographs used are presented in tables 12 and 13.

g. Antecedent flow. For the drainage area above Fulton, a reasonable estimate of the antecedent conditions indicated that all reservoirs above Fulton should be at 10 percent capacity including Millwood but excepting other Little River reservoirs which should be at 35 percent capacity. With reservoirs in operation at this level, the resulting flow produced at Fulton is 50,000 c.f.s. which corresponds to a flow of 70,000 c.f.s. with no reservoirs in operation. For the area below Fulton, consideration was given to the flow conditions at key locations on the lower Red River for the years of record (1932 to the present), and also to the flow at Fulton resulting from the runoff from upper Red River. The flow on 10 May 1944 was found to provide a satisfactory antecedent condition that would produce the desired unregulated condition at all key stations below Fulton and an appropriate relation to the antecedent conditions adopted above Fulton. The average flow for the 90-day period preceding May 1944 was approximately 25 percent above the average flow for the years of record (see par 3-02 d (1), page 16, Civil Works Bulletin 52-8 for antecedent flow criteria). The 10 May 1944 flow was assumed to have occurred on 8 May 1943 to conform to the SPS series. The two pertinent reservoirs below Fulton (Texarkana and Ferrells Bridge) were found, by routing of the antecedent flows, to be slightly above the bottom of their respective flood control pools which corresponds to an elevation that is slightly higher than normal for this time of year. The unregulated flows at Shreveport and Alexandria resulting from this antecedent condition were 101,900 c.f.s. and 136,800 c.f.s., respectively. Figures 25, 26, and 27 show the antecedent flow, flood flow, and total flow for three subbasins to indicate the

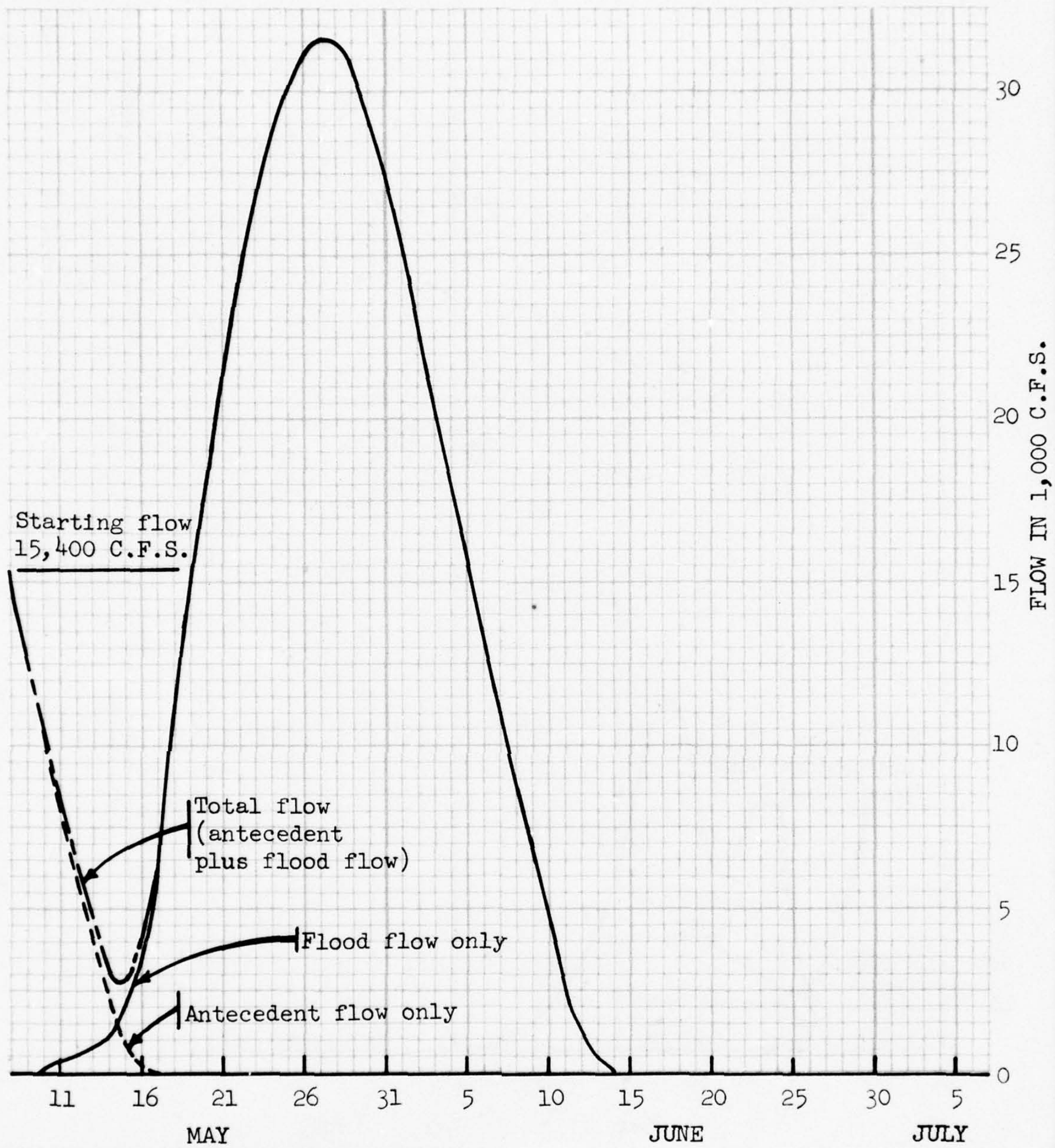


RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

ANTECEDENT FLOW HYDROGRAPHS FOR SUBBASIN NUMBER 9

JUNE 1968 FILE NO. H-2-24396

FIGURE 25

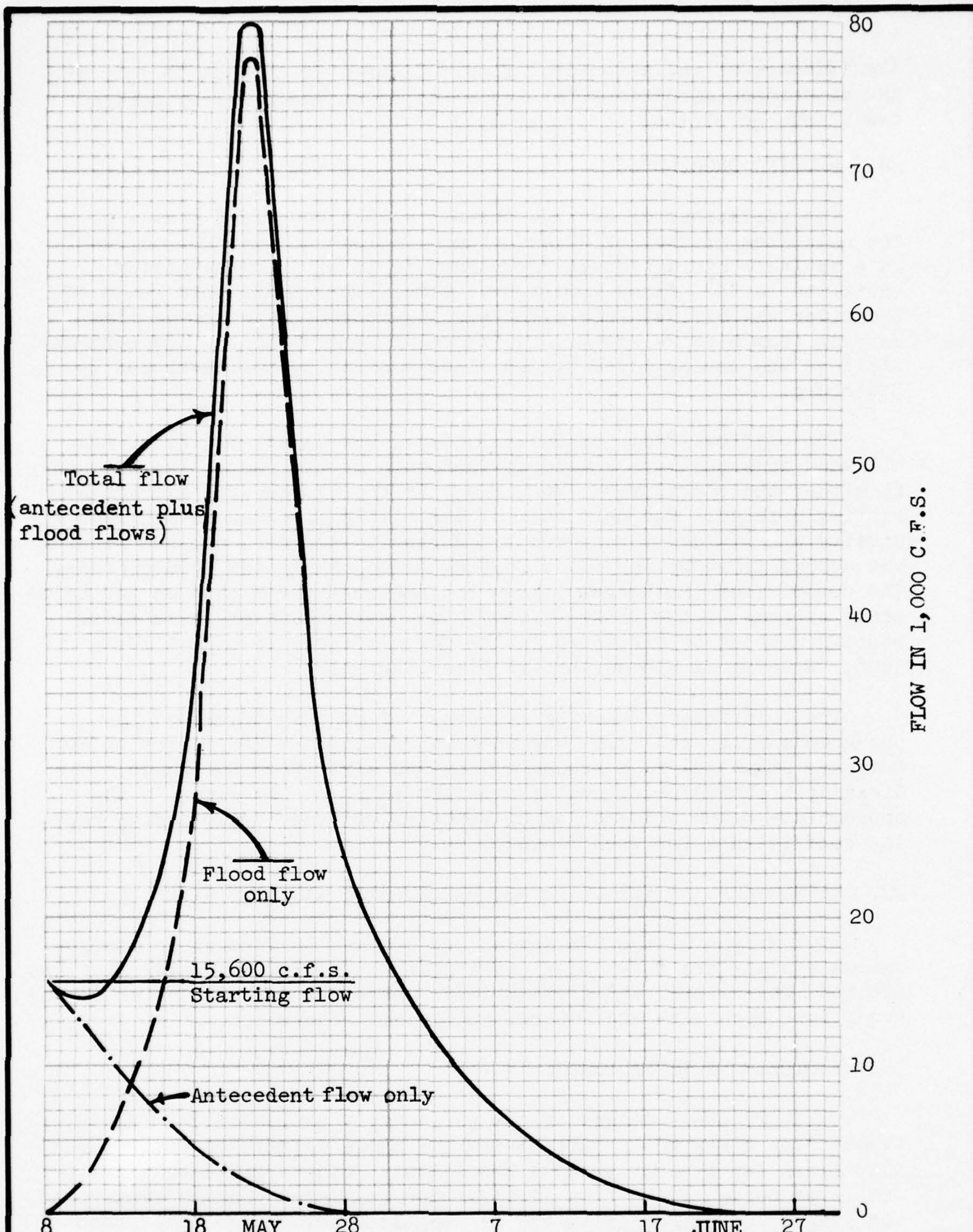


RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

ANTECEDENT FLOW HYDROGRAPHS FOR SUBBASIN NUMBER 11

JUNE 1968 FILE NO H-2-24396

FIGURE 26



RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

ANTECEDENT FLOW HYDROGRAPHS FOR SUBBASIN NUMBER 19

JUNE 1968 FILE NO. H-2-24396

FIGURE 27

significance of the antecedent flow. Figures 28 through 33 indicate the antecedent conditions for key stations on Red River by noting the discharge plotted for 8 May 1943.

28. ROUTING PROCEDURES

The variations of average channel widths and flood plains on the main stem of the Red River between Denison Dam and Fulton result in a variable storage discharge relationship with corresponding variation in "K", flood wave travel time. Therefore, this reach of the river was divided into eight routing reaches with travel time varying from 6 to 24 hours, and "X" values of 0 and .1. The routing of flows was accomplished by the flood routing method developed by Steinberg.

The outflows from the Boswell, Hugo, Pat Mayse, Big Pine, and Millwood damsites were routed to the mouth of the respective tributary by either the coefficient (Muskingum) or the progressive average-lag routing methods. The main stem of the Little River above Millwood damsite was divided into seven flood routing reaches, and the routing was accomplished by the flood routing method developed by Steinberg. The coefficient (Muskingum) flood routing method was used on the tributary streams of the Little River. The development of these flood routing methods is discussed in the Corps of Engineers EM 1110-2-1408, "Routing of Floods through River Channels."

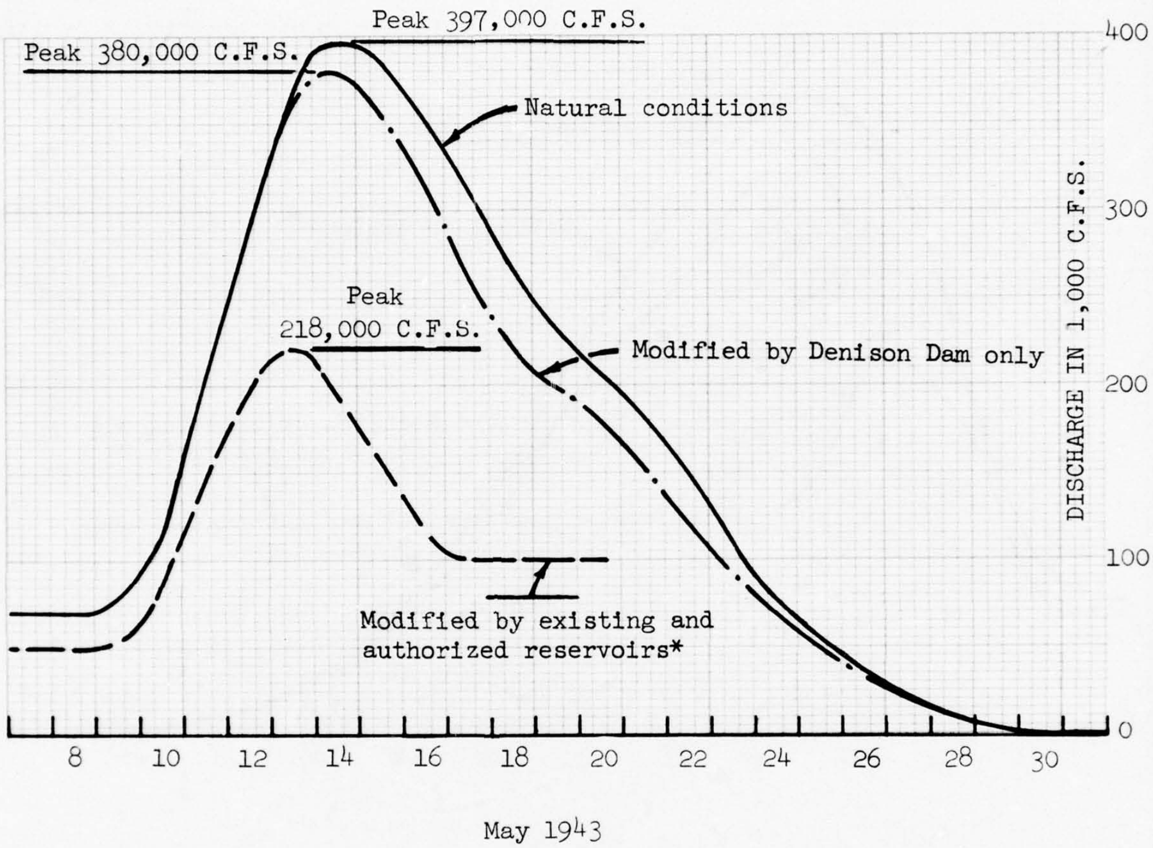
The coefficient (Muskingum) method of routing described in paragraphs 22.e. and 22.g. was used in routing the SPS series below Fulton. Figure 34 is a schema of the Red River from Fulton to Alexandria showing each subbasin inflow point on the river in the appropriate reach between gaging stations and the corresponding routing coefficients for each reach.

29. HYDROGRAPHS AT KEY STATIONS, UNREGULATED AND REGULATED

Hydrographs of the SPS series for 100 and 75 percent rainfall-excess amounts are shown on figures 28 through 33 for the key stations (Fulton, Shreveport, and Alexandria). These hydrographs are shown for conditions both with and without authorized reservoirs.

30. ADEQUACY OF LEVEE GRADES

Table 22 shows stages of the presently approved interim and ultimate flow lines and corresponding discharge capacities under these flow lines for present channel conditions. Stages and discharges for the levee design flood flow line for the realigned channel conditions and stages corresponding to the SPF regulated discharge under both present and realigned channel conditions are shown. The frequencies shown correspond to the discharges under regulated conditions (all authorized reservoirs in place). The relation of the discharges to



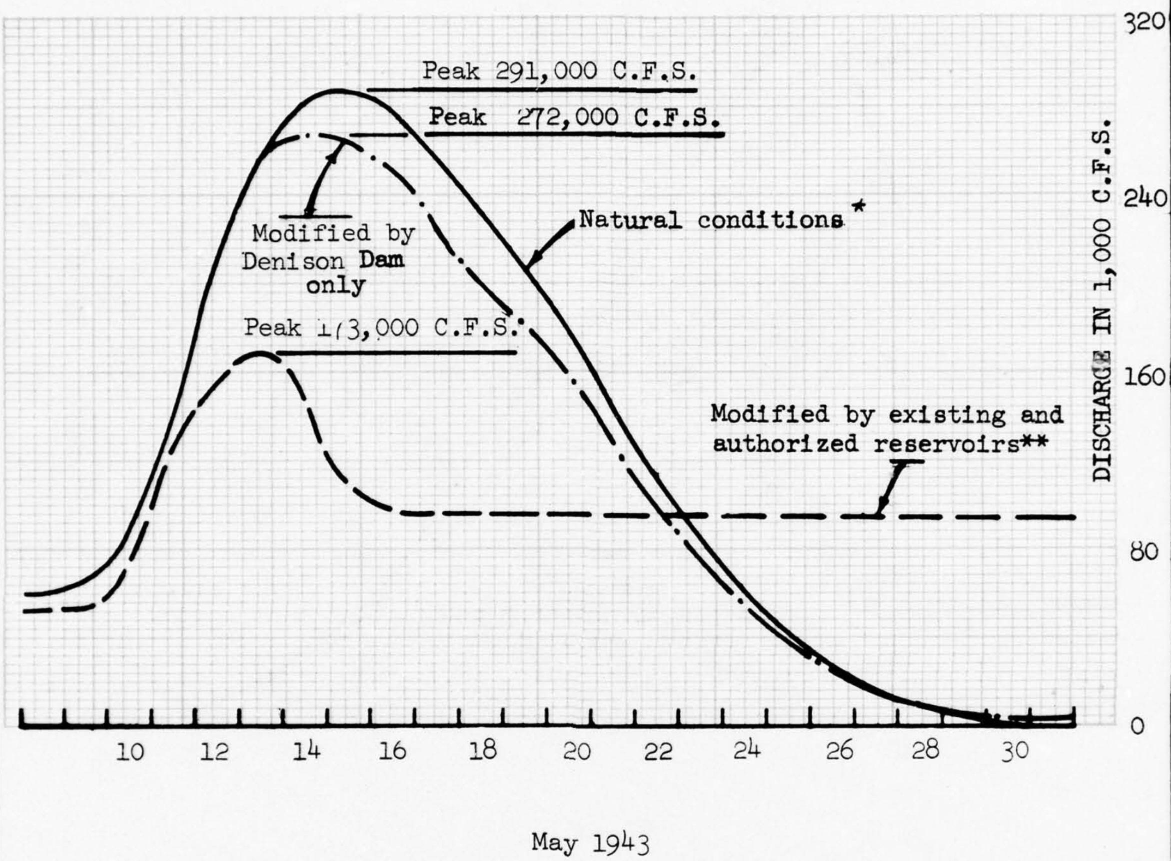
*Authorized reservoirs: Little River system, Hugo, Boswell, Pat Mayse, Big Pine, Clayton and Tuskahoma.

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

S.P.F. HYDROGRAPHS
AT FULTON, ARKANSAS

JUNE 1968 FILE NO. H-2-24396

FIGURE 28



*Confined without reservoirs
**Authorized reservoirs: Little River system, Hugo, Boswell, Pat Mayse, Big Pine, Clayton and Tuskahoma.

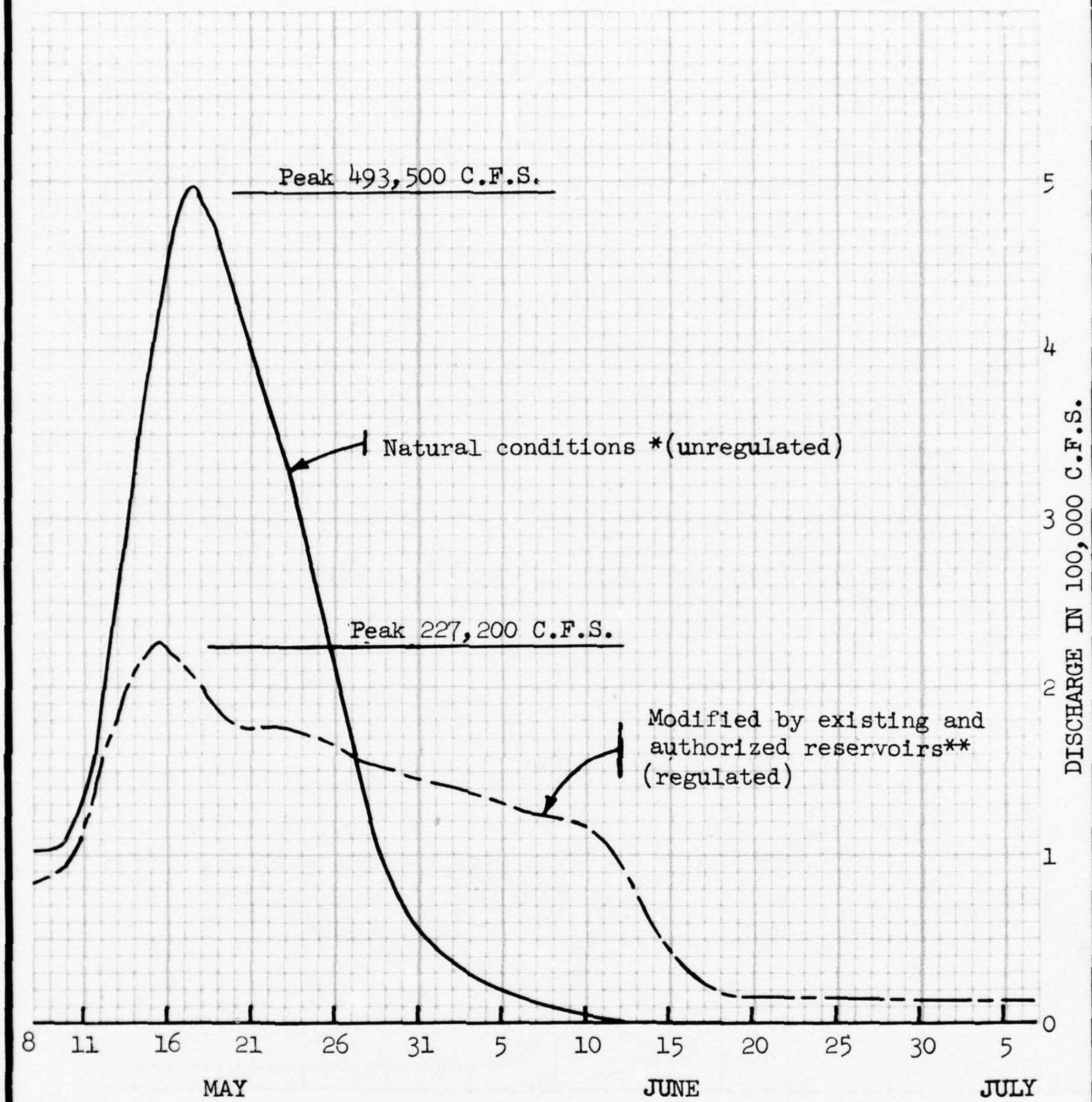
RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

S.P.F. HYDROGRAPHS AT FULTON, ARKANSAS REDUCED 25 PERCENT

JUNE 1968 FILE NO. H-2-24396

NOTE: Rainfall excess reduced 25 percent

FIGURE 29



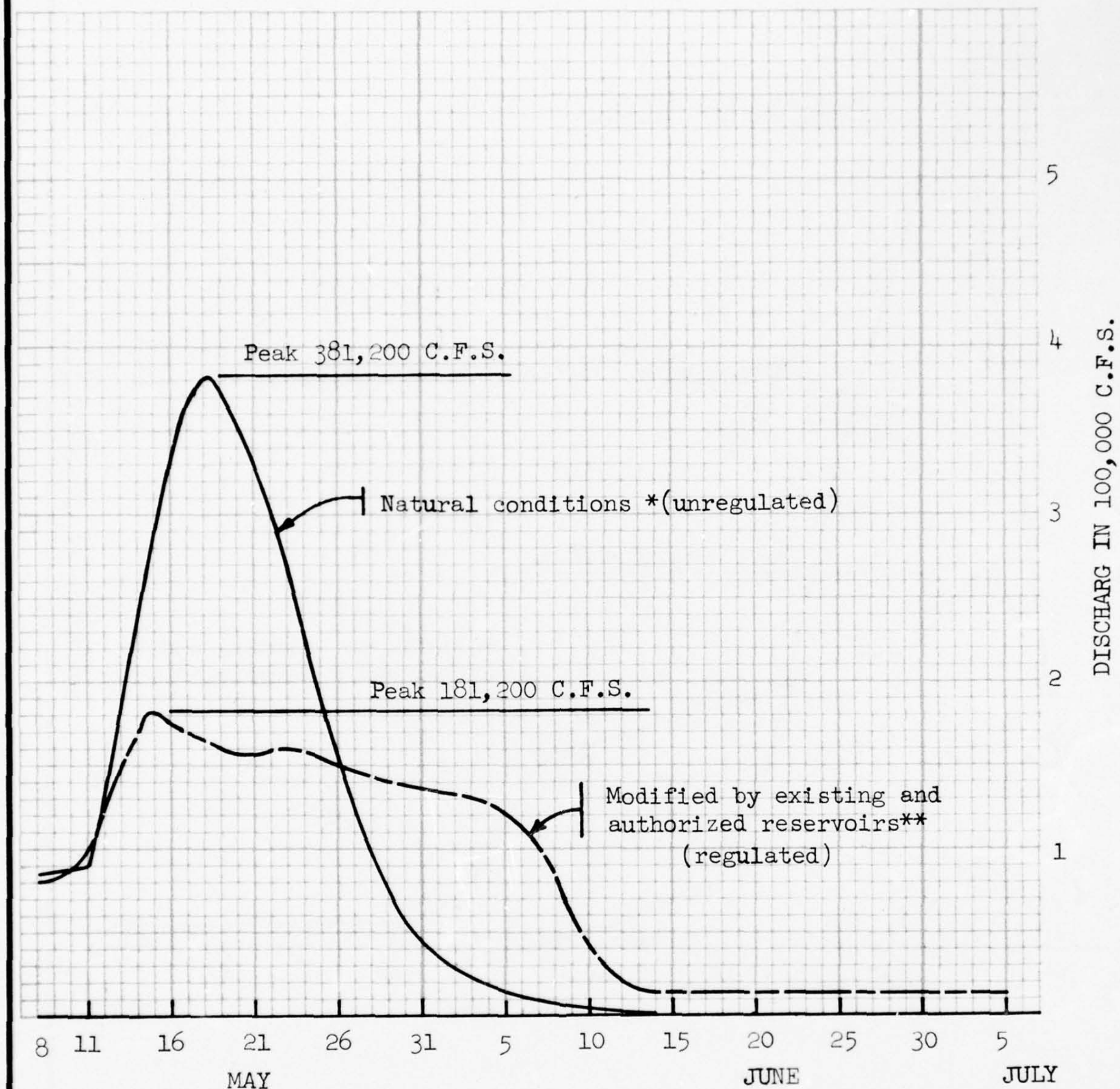
*Confined without reservoirs
**Authorized reservoirs: Little River system, Hugo, Boswell, Pat Mayse, Big Pine, Clayton, and Tuskahoma.

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

S. P. F. HYDROGRAPHS AT SHREVEPORT, LOUISIANA

JUNE 1968 FILE NO. H-2-24396

FIGURE 30



RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

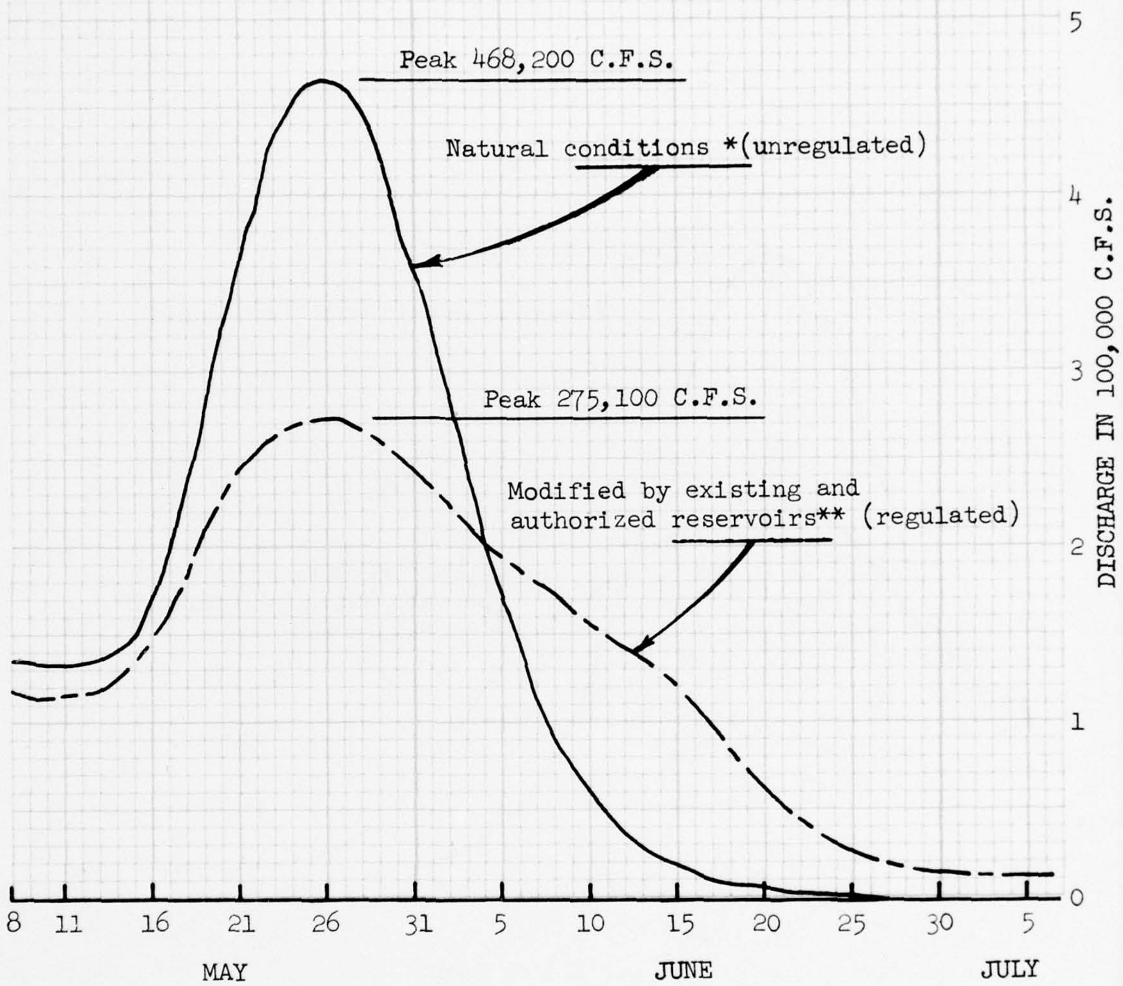
S.F.F. HYDROGRAPHS AT SHREVEPORT, LOUISIANA REDUCED 25 PERCENT

JUNE 1968 FILE NO. H-2-24396

Note: Rainfall excess reduced 25%

*Confined without reservoirs
**Authorized reservoirs: Little River system, Hugo, Boswell, Pat Mayse, Big Pine, Clayton, and Tuskahoma.

FIGURE 31



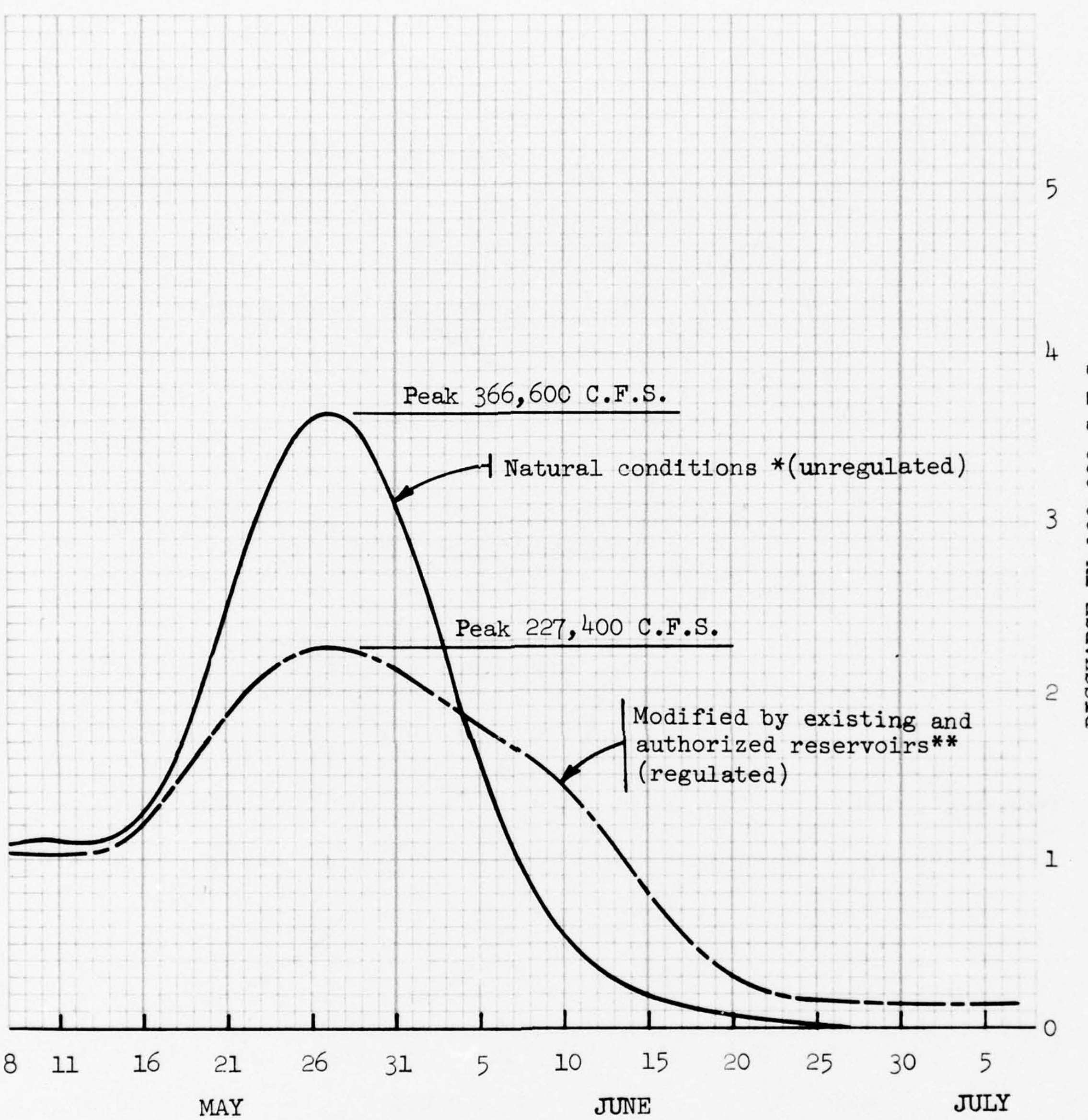
*Confined without reservoirs
**Authorized reservoirs: Little River system, Hugo, Boswell, Pat Mayse, Big Pine, Clayton, and Tuskahoma.

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

S. P. F. HYDROGRAPHS AT ALEXANDRIA, LOUISIANA

JUNE 1968 FILE NO H-2-24396

FIGURE 32



RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

S.P.F. HYDROGRAPHS AT ALEXANDRIA, LOUISIANA REDUCED 25 PERCENT

JUNE 1968 FILE NO H-2-24396

Note: Rainfall excess reduced 25%

*Confined without reservoirs
**Authorized reservoirs: Little River system, Hugo, Boswell, Pat Mayse, Big Pine, Clayton, and Tuskahoma.

FIGURE 33

TABLE 22

COMPARATIVE STAGES AND DISCHARGES FOR RED RIVER BELOW FULTON, ARK.

Location	Proposed mileage[1]	ULTIMATE AUTHORIZED FLOW LINE				INTERIM FLOW LINE				LEVEE DESIGN FLOW LINE				STANDARD PROJECT FLOOD FLOW LINE			
		Stage (ft msl)	Q[2] (1000 cfs)	Freq.[3] (Yrs)	% of SPF Q	Stage (ft msl)	Q[2] (1000 cfs)	Freq.[3] (Yrs)	% of SPF Q	Stage (ft msl)	Q[4] (1000 cfs)	Freq.[3] (Yrs)	% of SPF Q	Stage[4] (ft msl)	Q[2] (1000 cfs)	Q[3] (1000 cfs)	Freq.[3] (Yrs)
Fulton, Ark.	307.3	257.2	217	133	99	262.2	317	5/	145	254.1	195	100	89	255.5	190	218	133
Garland, Ark.	286.4	236.1	230	153	108	240.4	317	5/	145	232.1	195	100	89	233.7	190	218	133
Springbank, Ark.	261.3	209.9	280	200	94	217.9	415	5/	186	202	200	100	90	203.7	195	223	143
Miller Bluff	245.4	195.7	240	167	108	203.6	365	5/	163	188.7	200	100	90	190.5	195	223	143
Junction of Lone-star - Shreveport Waterway	219.0	168.6	240	167	108	176.5	365	5/	163	169.3	200	100	90	171.0	195	223	143
Shreveport, La.	212.3	164.3	188	77	83	171.2	303	5/	135	163.6	205	100	90	165.0	197	227	143
Coushatta, La.	165.9	133.1	200	72	79	137.5	258	5/	102	133.5	227	100	90	135.8	233	253	139
Grand Ecore	142.0	117.2	210	59	80	121.7	265	5/	101	118.3	237	100	90	120.1	245	263	138
Alexandria, La.	83.3	92.2	240	83	87	95.5	280	5/	102	91.9	255	100	93	93.8	260	275	131

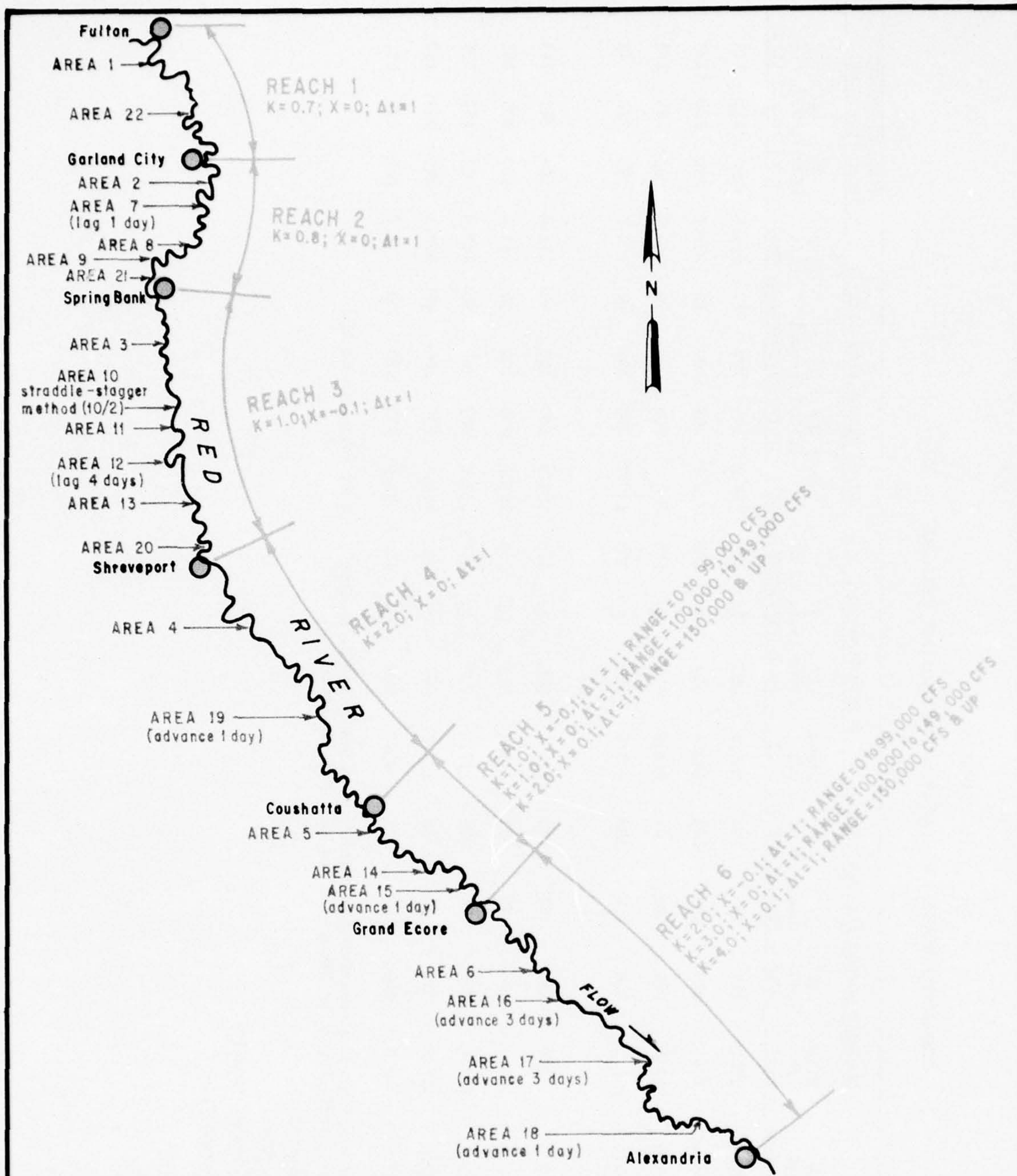
1/Mileage above Mississippi River along realigned channel proposed by the U. S. Army Corps of Engineers in the Comprehensive Basin Study - Interim Report on Navigation and Bank Stabilization.

2/Present channel capacity.

3/With reservoirs in place.

4/Stage - realigned channel capacity.

5/Exceeds the SPF frequency.



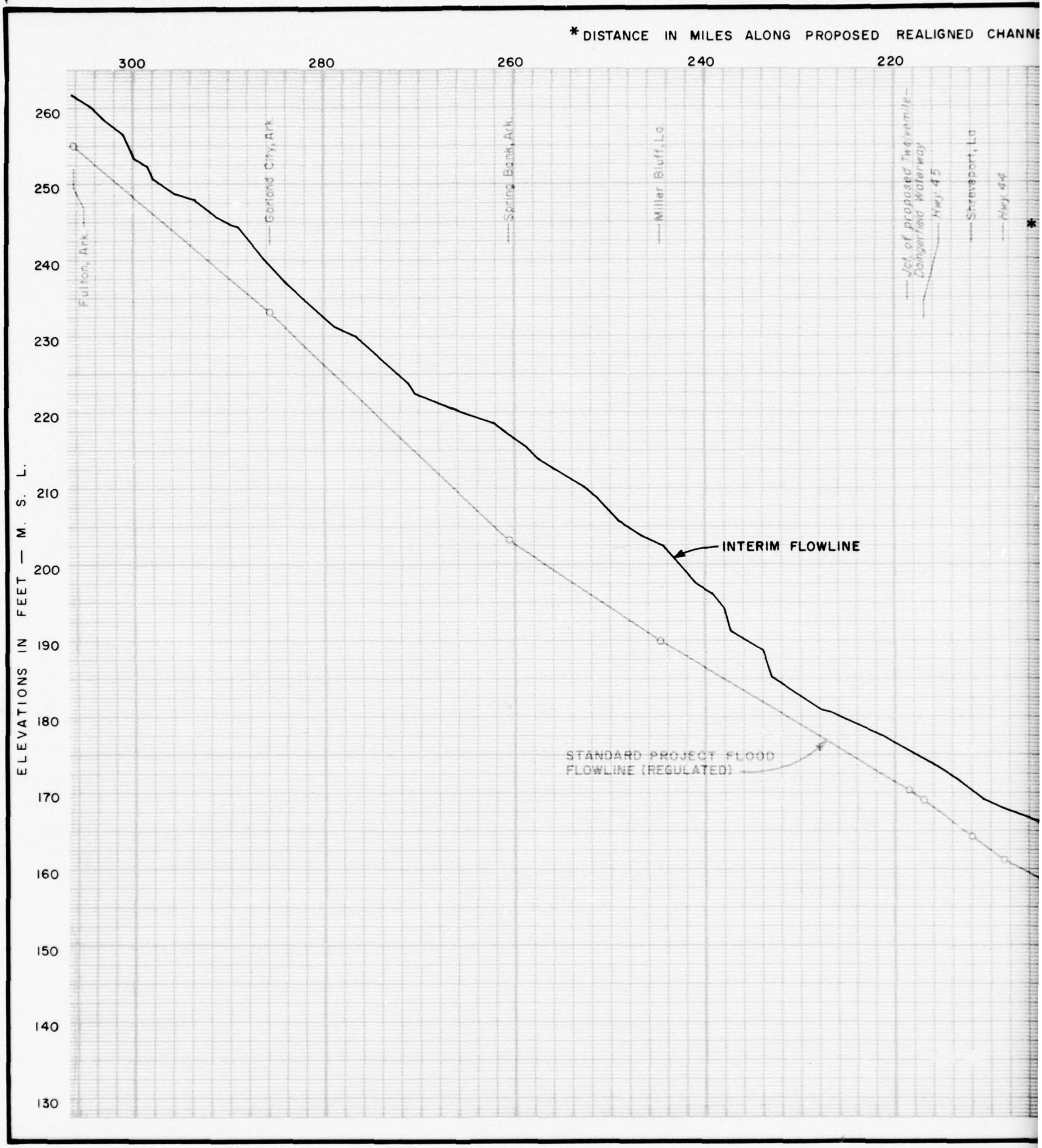
RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS
COMPREHENSIVE BASIN STUDY

ROUTING SCHEMATIC

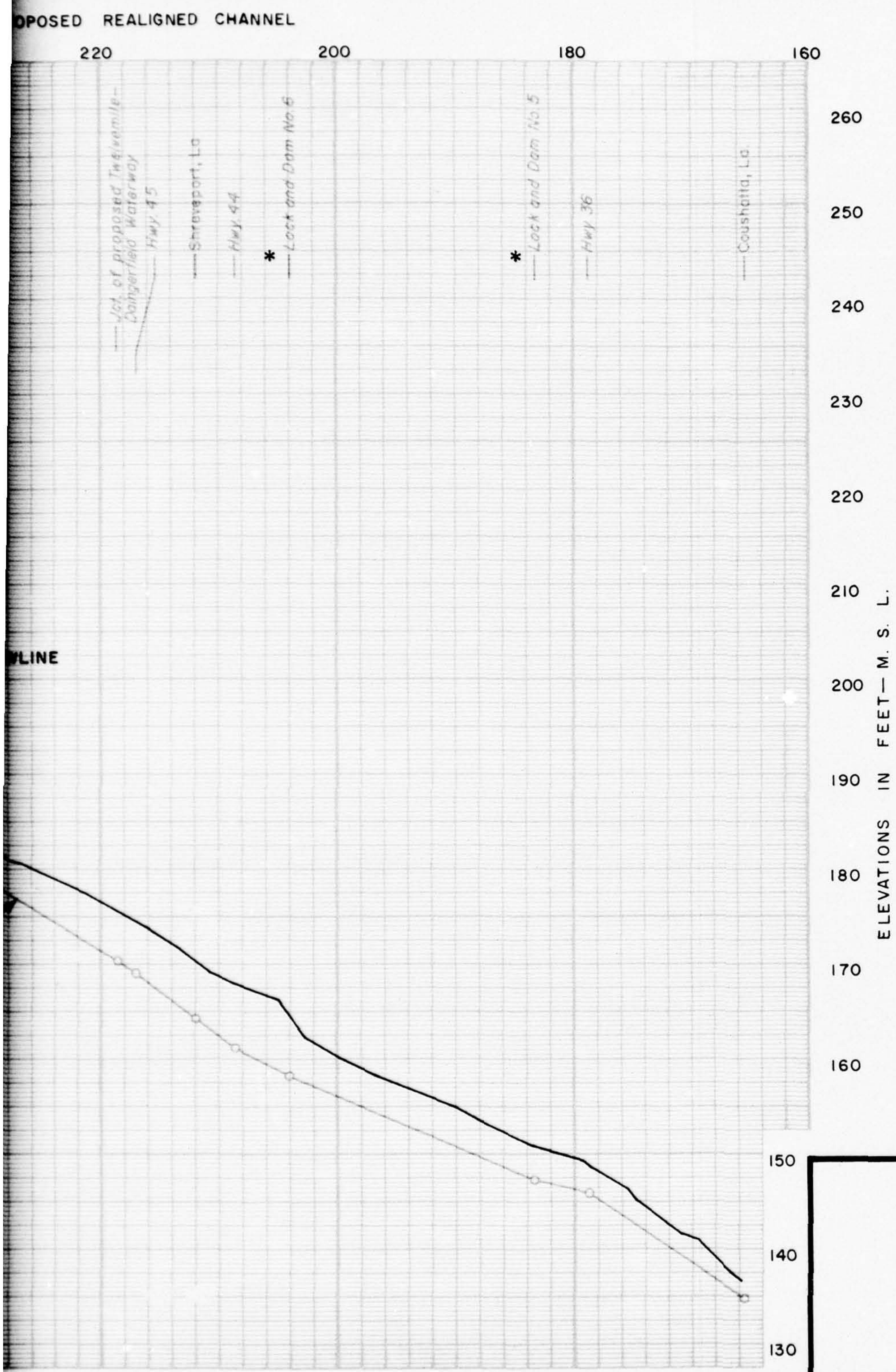
JUNE 1968 FILE NO. H-2-24396

NOTE:
Area flows combine with river flow at head of reach to obtain total inflow into the reach and then routed through reach.

FIGURE 34



*DISTANCE IN MILES ALONG PROPOSED REALIGNED CHANNE
300
280
260
240
220
ELEVATIONS IN FEET — M. S. L.
260
250
240
230
220
210
200
190
180
170
160
150
140
130
Fulton, Ark.
Garland City, Ark.
Spring Bank, Ark.
Miller Bluff, La.
Jct. of proposed Twelvemile-Daingerfield Waterway
Hwy. 45
Shreveport, La.
Hwy. 44
INTERIM FLOWLINE
STANDARD PROJECT FLOOD FLOWLINE (REGULATED)



NOTE:
* Refers to realigned channel, locks, and dams proposed by the U.S. Army Corps of Engineers in the Comprehensive Basin Study — Interim Report on Navigation and Bank Stabilization.

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS

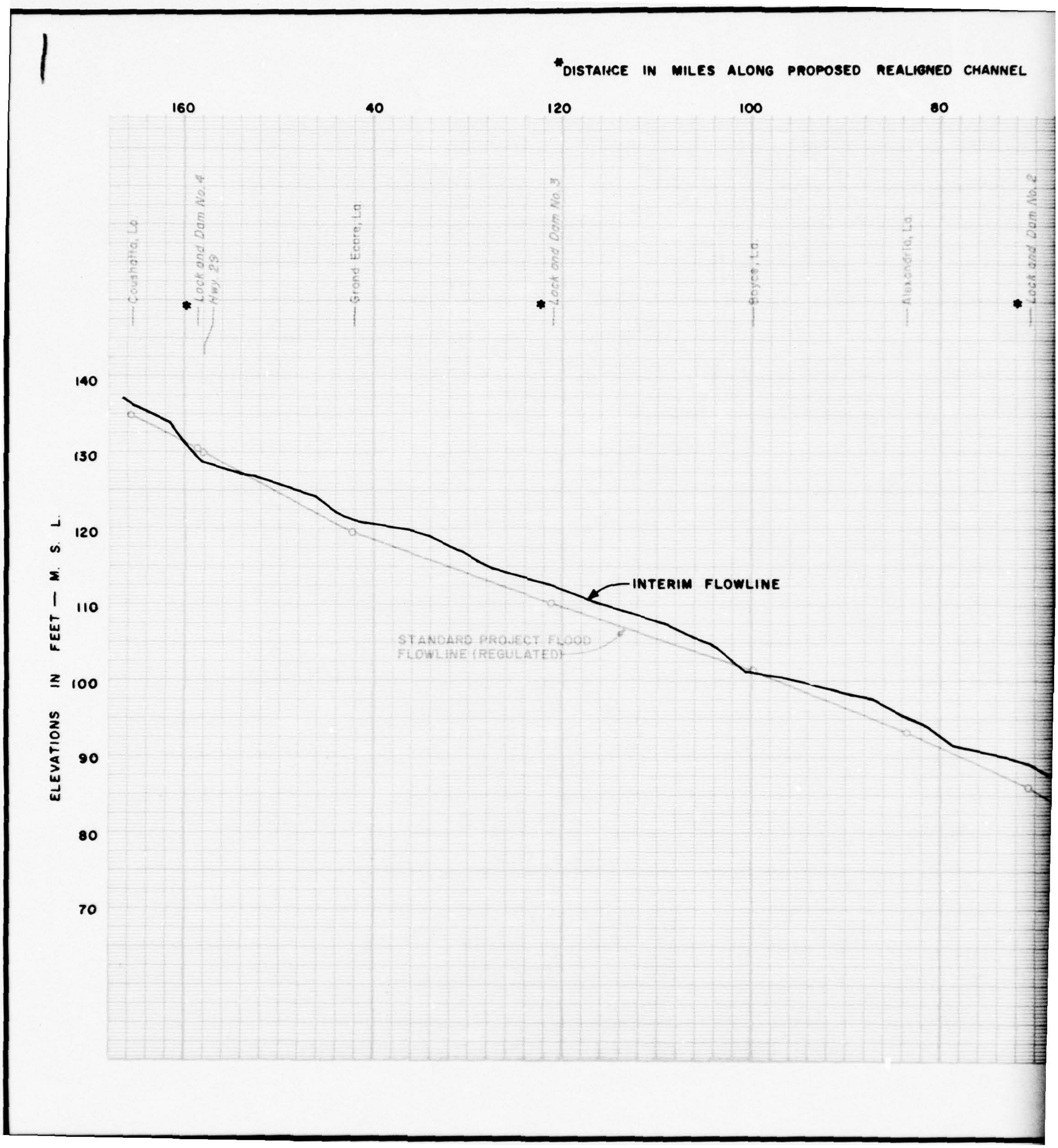
COMPREHENSIVE BASIN STUDY

COMPARATIVE WATER SURFACE PROFILES

FULTON, ARK., TO COUSHATTA, LA.

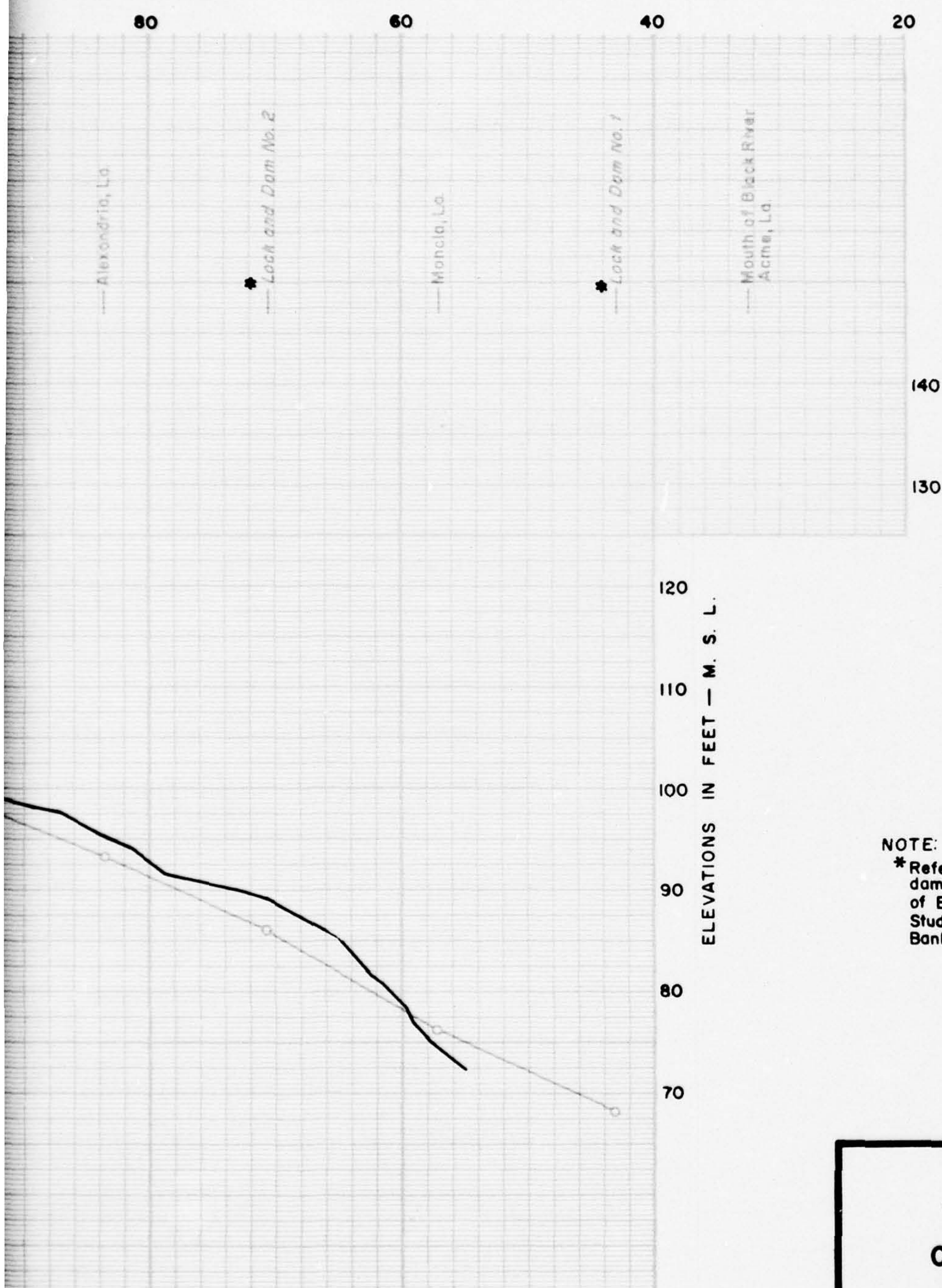
JUNE 1968 — FILE NO. H-2-24396

FIGURE 35



*DISTANCE IN MILES ALONG PROPOSED REALIGNED CHANNEL
160
40
120
100
80
Coushatta, La.
Lock and Dam No.4
Hwy. 29
Grand Ecore, La.
Lock and Dam No.3
Boyce, La.
Alexandria, La.
Lock and Dam No.2
ELEVATIONS IN FEET — M. S. L.
140
130
120
110
100
90
80
70
INTERIM FLOWLINE
STANDARD PROJECT FLOOD FLOWLINE (REGULATED)

ED REALIGNED CHANNEL



NOTE:
*Refers to realigned channel, locks, and dams proposed by the U.S. Army Corps of Engineers in the Comprehensive Basin Study – Interim Report on Navigation and Bank Stabilization.

RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS

COMPREHENSIVE BASIN STUDY

COMPARATIVE WATER SURFACE PROFILES
COUSHATTA, LA., TO MONCLA, LA.

JUNE 1968

FILE NO. H-2-24396

the SPF discharge is given as a percentage. Water surface profiles for the project flow line for interim conditions and the regulated SPF flow line under present channel conditions are shown in figures 35 and 36.

31. RELATIONSHIP TO DISCHARGE-FREQUENCY CURVES

The unregulated peak discharges for the SPS, the 75 percent SPS rainfall-excess amounts, and the slope of the unregulated peak discharge frequency curves were used to check the extrapolation of the regulated peak frequency curves which were developed, as discussed in paragraph 21.c., beyond experienced data at the key locations. The regulated peak discharges for the SPS and 75 percent SPS rainfall-excess amounts were plotted directly below the unregulated values at the same exceedence frequencies. These plotting positions for the SPF regulated values fell sufficiently near the regulated peak discharge frequency curves to obviate a change in the curves. Below is a listing of the recurrence interval and exceedence frequency per 100 years with the corresponding peak flows at the key locations.

Station	SPF peak flow (1,000 c.f.s.)	Exceedence frequency (events per 100 years)	Recurrence interval (years)
	100% UNREGULATED FLOW		
Fulton	397.0	0.90	111
Shreveport	493.5	0.70	143
Alexandria	468.2	0.60	167
	75% UNREGULATED FLOW		
Fulton	291.0	3.85	26
Shreveport	381.2	2.22	45
Alexandria	366.6	2.00	50
	100% REGULATED FLOW		
Fulton	218.0	0.72*	137*
Shreveport	227.2	0.70*	143*
Alexandria	275.1	0.78*	128*
	75% REGULATED FLOW		
Fulton	173.0	1.41*	71*
Shreveport	181.2	1.45*	69*
Alexandria	227.4	1.56*	64*

*Taken from the regulated curves.

32. RELATIONSHIP OF SPF TO LEVEE DESIGN FLOOD

Comparison of the SPF and the levee design flood (LDF, 100-year recurrence flood) shows that the SPF exceeds the LDF at all key locations. Shown below are the percentages of the SPS rainfall excess which, when routed under regulated conditions, would produce the levee design flows at the key locations.

Station	Levee design flow (1,000 c.f.s.)	Percentage of SPS rainfall excess
Fulton	195	87
Shreveport	205	88
Alexandria	255	89

These percentages were determined by establishing a relation between the LDF peak discharge and the SPF and 75 percent SPF peak discharges by interpolating the LDF between the 100 percent and 75 percent SPF peak discharges. The procedure was accomplished graphically as demonstrated on the discharge-frequency curves, figures 13, 14, and 15. For example, at Fulton, the LDF regulated peak flow of 195,000 c.f.s. was located on a straight line connecting the regulated SPF peak discharges of 100 percent and 75 percent (218,000 and 173,000 c.f.s., respectively). This location established the exceedence frequency and magnitude corresponding to the LDF under unregulated conditions. The relation between the rainfall excesses for the unregulated LDS and SPS is given below:

$$\frac{1 - X}{397{,}000 - 340{,}000} = \frac{1 - 0.75}{397{,}000 - 291{,}000}$$

$$X = 0.87$$

33. ROUTINGS IN RESERVOIRS BELOW FULTON, ARKANSAS

In routing the SPF through Texarkana and Ferrells Bridge Reservoirs the conditions which existed on 10 May 1944 were assumed to be the actual conditions which existed on 8 May 1943. On this basis, the starting pool elevations for Texarkana and Ferrells Bridge Reservoirs were assumed at 226.0 and 228.8 feet m.s.l., respectively. These two elevations are slightly higher than would normally be expected for this time of year but considering the high antecedent rainfall condition, they are reasonable. The starting storages for Texarkana and Ferrells Bridge Reservoirs were 299,000 acre-feet and 260,000 acre-feet, respectively. The peak storages for the SPF were 1,886,400 acre-feet in Texarkana Reservoir and 730,500 acre-feet in

Ferrells Bridge Reservoir which correspond to elevations of 252.5 and 246.5 feet m.s.l., respectively. Texarkana and Ferrells Bridge can store 3,482,000 acre-feet and 1,113,000 acre-feet, respectively, with corresponding elevations of 265.8 and 256.0 feet, before uncontrolled overflow occurs. The SPS rainfall excess in these two subbasins could be 221 percent and 197 percent larger, respectively, without inducing uncontrolled overflow.

CHAPTER VIII - MANAGEMENT CONSIDERATIONS

The potential for development of ground-water supplies in the lower Red River Basin is of vast scope. The fresh-water aquifers that underlie the basin are capable of yielding many times the quantities of ground water presently (1966) being utilized. (The 1960 withdrawal rate was approximately 70 m.g.d.) Because of its widespread availability, ground water has special significance in the consideration of the future water needs of the basin.

The abundance of ground water does not preclude problems concerning its development and management. Large withdrawals from the artesian aquifers, particularly in the vicinity of Sherman and Bonham, Texas, have depressed water levels to the extent that pumps must be repeatedly lowered. As water levels decline, the economic penalty attached to greater pumping lifts will tend to limit the full development of the aquifer. In order to minimize additional declines in water levels, future wells should be spaced as far apart as economically possible. Other solutions might include artificial recharge of the artesian aquifers, either by reservoirs on the outcrop areas or by direct injection of excess surface water to the aquifer, and development of surface-water supplies to supplement the withdrawals from ground-water reservoirs.

The hydrologic effects on the alluvial deposits in the Red River Valley that will result from construction of proposed navigation structures should be studied in detail in order to evaluate the beneficial and adverse effects of changes in ground-water levels. If stream levels are maintained at higher than normal stages, the aquifer will discharge at a higher level and the amount of water in storage will increase. Thus, greater ground water yields will be possible at lower costs. However, studies conducted by the U. S. Geological Survey indicate that the increased heads in the river, created by locks and dams, may also cause waterlogging in some places.

Salt water encroachment, although a minor problem at the present time, may become more significant in the future, as ground water is utilized in greater quantities. At present, only relatively small areas in the vicinity of Sherman, Texas, in the lower Little River Basin, and in Natchitoches Parish, Louisiana, have been contaminated by upward seepage of salt water from saline water-bearing formations. Local large-scale development of ground water elsewhere in the basin may cause a significant reduction of head in the fresh water aquifers, and result in the contamination of additional areas by salt water. Wherever a substantially increased demand for water is anticipated, continuous measurements of water levels and water quality are needed to evaluate the effect of ground water development on available supply.

Ground water should not be considered as a source of supply in the Ouachita Mountains, unless the quantity needed is small. Tributary streams in the Ouachita Mountains are the best potential source of water for municipal growth and economic development. With adequate storage facilities, surface water is the most reliable, and in many places, the only source of supply where water demands approach 50,000 g.p.d.

Proper management of the water resources must be based on knowledge concerning the distribution and potential for development of this resource, as well as knowledge of the functioning of the hydrologic system. Studies conducted in the past have added greatly to the knowledge of the water resources in parts of the basin. However, additional areal investigations and specific site studies will be necessary to determine the exact potential of the basin's aquifers. Because of the heterogeneous nature of these aquifers, future developments should be preceded by detailed hydrologic investigations. A systematic data-collection plan would provide a base of information from which a realistic water-resources-management program could be made in the future.

CHAPTER IX - DISCUSSION

Abundant supplies of ground water are available throughout most of the lower Red River Basin. The greatest potential for ground-water development is in the alluvial deposits which underlie the flood plain of the Red River. Wells drilled into the alluvial deposits yield as much as 500 g.p.m. in Texas and Oklahoma, as much as 1,000 g.p.m. in Arkansas, and as much as 1,700 g.p.m. in Louisiana. The thickness of the alluvium ranges from about 60 feet in Grayson County, Texas, to about 100 feet near Alexandria, Louisiana.

Moderate supplies of ground water are available from formations of Cretaceous and Tertiary age, which underlie a major part of the lower Red River Basin. Wells drilled into these formations range from 100 to 800 feet in depth, but are more than 1,200 feet deep in Red River, Lamar, Hunt, Delta, Fannin, and Grayson Counties, Texas, and in the vicinity of Hope, Arkansas. The yields of wells that tap aquifers of Cretaceous or Tertiary age range from 300 to 500 g.p.m. However, wells that tap the Sparta Sand in Columbia and Lafayette Counties, Arkansas, and in eastern Bossier, Webster, Claiborne, Bienville, Natchitoches, and Winn Parishes, Louisiana, yield as high as 1,500 g.p.m. In small areas scattered throughout the basin, and particularly in the upper Muddy Boggy, Kiamichi, and Little River Basins, there seems to be little potential for extensive ground-water development.

Ground water from nearly all the principal fresh-water aquifers is of good quality, and generally is suitable for municipal or industrial use with little or no treatment. The chief characteristics of the water, particularly that from the Red River alluvium, are its high iron content and high degree of hardness. Water from the formations of Tertiary age generally is unsuitable for continuous irrigation use.

The rivers of the study area are good potential sources of water for municipal growth and economic development, but, because of the wide variations in the streamflow, storage facilities are necessary to provide a dependable supply of water.

The variations in the low-flow characteristics of the streams in the basin may be attributed to the depth to which the streams are incised, the relation of the water table to the bed of the stream, and to the porosity and permeability of the aquifers in the immediate areas. The low-flow indices for streams in the basin range from 0 to 0.2 c.f.s. per square mile. Streams having the highest low-flow indices are in the Saline Bayou and Bayou Dorcheat Basins. These streams are incised into the Sparta Sand, which is a prolific source of ground water.

Water in the tributary streams generally is of good chemical quality, even during periods of low streamflow, and is suitable for municipal and many industrial uses with little treatment. In many streams where poor quality occurs during low flows, the probable cause is oilfield or industrial contamination.

Red River water has a high chloride, sulfate, and dissolved-solids content, and is moderate to very hard. It would not be suitable for municipal use or for most industrial uses without treatment.

Historical records of rainfall and streamflow indicate that, subsequent to 1900, major flooding on Red River occurred in 1908, 1927, 1930, 1938, 1945, 1957, and 1958. Since 1900, lesser floods occurred in 1902, 1903, 1905, 1915, 1920, and 1953. Two of the greatest floods of record are those of 1938 and 1945, each with different characteristics as to origin and effect. The 1938 flood resulted primarily from heavy runoff in the upper portion of the basin and produced larger peak discharges in the upper basin. The 1945 flood was characterized by large contributions of runoff from almost all areas in the basin and produced the highest peak discharges in the lower portion of the basin.

The construction of reservoirs, completed and anticipated, and the leveed floodway of Red River significantly influence flood characteristics in the basins. Under present channel conditions with authorized improvements, discharges for the authorized ultimate levee flow line will be about 99 percent of those estimated for the standard project flood in the vicinity of Fulton, Arkansas, about 83 percent in the vicinity of Shreveport, Louisiana, and about 87 percent in the vicinity of Alexandria, Louisiana. Design discharges for the planned navigation and bank stabilization improvements will be about 90 percent of those estimated for the standard project flood for the river between Fulton and Alexandria.

Floods on the tributaries of Red River occur at frequent intervals coinciding generally with Red River floods. Where intense local storms produce flood conditions on a single tributary, the Red River as a whole is not materially affected.

RED RIVER BELOW DENISON DAM
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS
COMPREHENSIVE BASIN STUDY

APPENDIX IV

FLOOD CONTROL AND MAJOR DRAINAGE

Prepared by
U. S. Army Corps of Engineers

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SUMMARY

Existing projects provide a high degree of protection to large areas of the Red River Valley. Twelve areas are experiencing flood damages sufficient to justify construction of improvements in the next 10-15 years. Details of the plans developed for these areas are contained in appendix XV, "Plan Formulation." It is estimated that, over the 100-year study period, flood protection improvements for an additional 30 areas will become feasible. These improvements have been placed in the long-range plan of development. Basin plans should be reviewed approximately every 15 years to determine precisely when these improvements should be undertaken. Construction of these improvements, when justified, should reduce flood damages to the minimum practicable level.

APPENDIX IV

FLOOD CONTROL AND MAJOR DRAINAGE

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CHAPTER I - INTRODUCTION

1. PURPOSE AND SCOPE

This appendix presents the results of an analysis of flood control and major drainage problems along the Red River and its major tributaries below Denison Dam. Similar problems along the smaller tributaries and in the upstream watersheds are analyzed in appendixes V, "Upstream Watershed Protection, Use, Management, and Development;" and VII, "Drainage and Flood Prevention on Flatlands," prepared by the U. S. Department of Agriculture.

This appendix presents data on flood control and major drainage needs in areas subject to fluvial flooding; information on prospective increases in flood damages due to future developments; investigation of projects to satisfy short-term (10-15 years) needs; and possible solutions for long-range (100 years) problems.

2. DESCRIPTION OF BASIN

The Red River Basin below Denison Dam (excluding the Ouachita-Black River Basin) covers 29,500 square miles located in southeast Oklahoma, northeast Texas, southwest Arkansas, and northwest Louisiana. The watershed boundaries are shown on plate IV-1. Drainage area data on the Red River and its tributaries below Denison Dam are contained in table 1. Part of the basin, about 7,000 square miles, in Arkansas and Oklahoma is an area of high relief (elevation 600-2000 feet above mean sea level*) characterized by narrow steep-sided valleys and ridges. The remainder of the basin, an area of lower relief with elevations below 600, is divided between the West Gulf Coastal Plain and the Mississippi Alluvial Plain geologic provinces. The latter borders on and slopes toward the Gulf of Mexico. The alluvial valleys of the Sulphur, Red, and Mississippi Rivers comprise a large portion of the lower region, and are characterized by meandering stream courses, natural levees, oxbow lakes, and abandoned stream channels. In the past, the three rivers have eroded new channels, cut off loops, and deposited sediments in the overflow areas as they meandered within

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*All elevations contained in this appendix are in feet and refer to mean sea level (m.s.l.) unless otherwise specified.

TABLE 1

PERTINENT DATA ON THE RED RIVER AND ITS TRIBUTARIES
BELOW DENISON DAM*

Stream	Drainage Area (sq. mi.)	Stream Length From Mouth (miles)	Tributary Of	River Mile
Red River, Main Stem below Denison Dam	29,500	675	-	-
Tributaries				
Choctaw Creek	263	28	Red River	657.7
Island Bayou	148	31	Red River	631.5
Blue River	676	150	Red River	618.0
Bois d'Arc	416	52	Red River	611.8
Boggy Creek	2,429	25	Red River	591.5
Clear Boggy Creek	1,010	88	Boggy Creek	24.4
Muddy Boggy Creek	1,218	131	Boggy Creek	24.4
North Boggy Creek	231	38	Muddy Boggy Creek	55.6
McGee Creek	175	38	Muddy Boggy Creek	34.6
Sanders Creek	190	33	Red River	584.5
Pine Creek	192	34	Red River	567.0
Kiamichi River	1,830	169	Red River	555.0
Jack Fork Creek	280	24	Kiamichi River	103.5
Tenmile Creek	104	28	Kiamichi River	67.3
Cedar Creek	172	28	Kiamichi River	54.2
Big Pine Creek	166	27	Red River	534.0
Mud Creek	84	22	Red River	525.0
Pecan Bayou	175	33	Red River	509.9
Walnut Bayou	134	20	Red River	454.0
Little River	4,260	217	Red River	407.0
Glover Creek	338	56	Little River	127.9
Mountain Fork River	842	95	Little River	87.1
Rolling Fork River	354	50	Little River	72.9
Cossatot River	530	87	Little River	43.5
Saline River	552	85	Little River	22.8
McKinney Bayou	360	44	Red River	339.3
North Sulphur River	449	53	Sulphur River	183.0
South Sulphur River	675	72	Sulphur River	183.0
Middle Sulphur River	133	25	South Sulphur River	28.4
Sulphur River	3,748	183	Red River	335.0
Cuthand Creek	403	49	Sulphur River	141.3
White Oak Creek	773	90	Sulphur River	107.4
Twelvemile Bayou	3,522	143	Red River	277.6
Black Cypress Creek	401	48	Twelvemile Bayou Cypress Creek	53.6
Little Cypress Creek	696	64	Twelvemile Bayou Cypress Creek	51.1
James Bayou	411	34	Twelvemile Bayou	29.5
Black Bayou	384	61	Twelvemile Bayou	22.4
Wallace Bayou	276	39	Bayou Pierre	64.2
Bayou Pierre	1,138	84	Red River	185.0
Cane River-Kisatchie Bayou	764	69	Red River	133.5
Bayou Jean de Jean	92	19	Red River	125.8
Bois d'Arc Creek	220	29	Red River	391.0
Maniece Bayou	118	26	Red River	346.7
Posten Bayou	114	20	Red River	320.2
Loggy Bayou	2,649	135	Red River	267.5
Bayou Bodcau, Red Chute, and Flat River	1,149	137	Loggy Bayou	7.8
Bayou Dorcheat	1,173	100	Lake Bistineau	34.9
Saline Bayou	1,405	99	Red River	166.1
Black Lake Bayou	960	100	Saline Bayou	12.0
Nantachie Creek	81	28	Red River	146.8
Bayou Rigolette	418	65	Red River	106.0

*These data extracted from "Drainage Area Data, Arkansas, White and Red River Basins" except for mileages along the Red River Main Stem which are based on 1957 data.

their flood plains. Settling of coarser materials during floods has built natural levees, more or less contiguous to the streams, while deposits of finer particles have formed a relatively impervious blanket in the more distant slack water areas.

At the present time, an essentially continuous system of manmade levees exists on both banks of the Red River from Bowie County, Texas (northwest of Texarkana), to below Alexandria, Louisiana. These levees, together with headwater reservoirs on the main stem and tributary streams, afford a high degree of protection to the very fertile valley lands. However, uncontrolled runoff in some tributary areas; sluggish, tortuous, and inadequate outlets from certain of the leveed areas; and the remaining gaps in the main stem levees continue to cause significant flood losses.

The climate of the basin is generally mild with long summers. Average annual precipitation varies from about 38 inches at the western extremity of the basin to about 56 inches in sections in the east.

3. BASIN ECONOMIC DEVELOPMENT

a. Trends. Since the middle 1930's the economy of the Red River Basin below Denison Dam has shifted from primarily agricultural to a more diversified structure. An increase in farm mechanization plus changes in cropping practices have resulted in a long-term decline in agricultural employment. This decline, combined with the availability of higher paying jobs in the cities, has resulted in migration to the urban areas. The resulting expansion of urban areas and the introduction of industry to utilize natural resources have increased the value of the physical property subject to flood damage. The conversion of timbered lands to cultivated fields, made possible by mechanization, and the increase of impervious areas within the urban areas have increased the rate and volume of runoff, concomitantly aggravating the residual flood threat.

b. Projections. Because of the basin's untapped natural resources and potential for development compared to other areas where the population saturation and full resource utilization limit opportunity for expansion, industries seeking new locations will find the basin increasingly attractive. Since the tributary streams usually head in rugged, sparsely settled areas, it is logical for industries to look to established downstream urban areas. As the urban areas expand, the necessity for proper flood plain management will assume greater importance. The region is subjected to intermittent periods of drought. To meet these periods of need, it will become imperative to conserve floodflows for use during periods of need. Surface waters of the area are generally of high quality.

Substantial reduction of flood damages on the main stem of the Red River and on its tributaries has been achieved through the function of existing projects, and the construction of projects now authorized will further reduce the flood threat. This report will present plans to enhance the protection provided by existing and authorized projects, and to extend protection to new areas. Those projects found economically justified under current economic conditions are included in the "early-action," or "10-15 year" plan. Additional projects or programs considered feasible for the protection of future industrial developments, expanding urban areas, and increasingly intensive agricultural activities, are included in the long-range plan of development.

c. Land-use patterns. Increased farm mechanization, changes in the cropping practices, and a trend toward efficiently operated, corporation-size farming units in the basin have spurred the conversion of timberland to higher uses. The lands in the basin potentially most productive are those in the highly fertile alluvial bottoms along the Red River. An expanding world population will necessitate maximum agricultural production from highly fertile areas such as the Red River Valley. Projects must be developed, over the next 100 years, to provide protection for all of these suitable alluvial bottom lands if the lands in the basin are to make their optimum contribution to the national economy.

4. STUDY BREAKDOWN

Because of the differences in flood characteristics and topography of the individual areas, separate studies were made of flood problems along the main stem of the Red River and along each of its main tributaries. Economic losses are caused by four distinct types of flooding which are identified and defined as follows:

a. Headwater flooding along the main stem: Lands adjacent to the Red River are flooded due to high stages in the river caused by excessive rainfall over all or a large portion of the Red River Basin.

b. Headwater flooding along tributary streams: Lands along tributary streams are flooded because of excessive rainfall in the particular tributary basin.

c. Backwater flooding: Where there is an uncontrolled connection of a tributary stream with the Red River, high stages in the river cause water to "back up" the tributary stream. Flooding of this nature is usually limited to the lower reaches of the tributary basins.

d. Ponding: Water may pond behind levees where drainage outlets are either inadequate or become inoperative because of high stages on the Red River.

Flooding in the basin can result from any of these conditions occurring singly or in combination.

5. FLOOD HISTORY OF BASIN

Storms which produce major floods on the main stem of Red River below Denison Dam are usually of large areal extent and cause flooding on several tributaries. Smaller high-intensity storms can cause major flooding on individual tributaries without causing significant overflow on the main stem of Red River. Flood occurrences on the main stem increase in frequency downstream from Denison Dam as the river traverses increasingly humid regions. Detailed information on floods of record and flood discharges and stages for the main stem of the Red River and for all its major tributaries are contained in appendix III, "Hydrology, Surface and Ground Water, and Geology."

6. EXISTING AND AUTHORIZED FLOOD CONTROL PROJECTS

a. Corps of Engineers projects. Corps of Engineers flood control projects specifically authorized by the U. S. Congress are shown in tables 2 and 3. The total estimated cost of these projects is about $403,000,000. They are discussed below:

(1) Red River below Denison Dam, Arkansas, Louisiana, Oklahoma, and Texas. The Flood Control Act of July 24, 1946, approved a general plan for flood control on Red River below Denison Dam which provides for construction of, inter alia, six flood control reservoirs in combination with existing or authorized Federal and non-Federal levee improvements, modified as required, and construction of bank protection works at locations where levee setbacks are impossible or uneconomical. The Act further provided for incorporation into the project of the several separate authorized Federal projects for flood control along Red River below Denison Dam. By Flood Control Acts of August 3, 1955, July 3, 1958, July 14, 1960, and October 23, 1962, the project was amended to include a number of additional reservoirs on tributaries, and other local protection works. Existing, under construction, and authorized flood control projects, as of June 30, 1967, included under this plan are noted with asterisks in tables 2 and 3. The total estimated cost of the project is about $388,000,000.

(2) The Pat Mayse Reservoir, Texas, was authorized by the Flood Control Act of October 23, 1962. It will have a total storage capacity of 189,100 acre-feet, with 64,600 acre-feet being allocated to flood control. As of June 30, 1967, construction was about 90 percent complete with completion scheduled during 1968. Estimated total cost of the project is $7,700,000.

TABLE 2

EXISTING, UNDER CONSTRUCTION, AND AUTHORIZED PROJECTS
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS

Project	Stream	Total Storage (ac-ft)	Flood Control Storage (ac-ft)	Status	Estimated Cost	Purpose(1)
*Bayou Bodcau and Tributaries Ark. and La.	Bayou Bodcau, Red Chute and Loggy Bayous	-	-	Authorized	$ 2,110,000	FC
*Campti-Clarence Area, La.	Red River	-	-	Under Const.	1,950,000	FC
*Cooper Reservoir and Channels, Tex.	South Sulphur River	441,400	131,400	(2)	26,300,000	FC, WS
*East Point, La.	Red River	-	-	Complete	479,000	FC
*Ferrells Bridge Dam (Lake O' the Pines), Tex.	Cypress Creek	842,100	587,000	In Operation	14,382,000	FC, WS
*Garland City, Ark.	Red River	-	-	Under Const.	1,280,000	FC
*Mooringsport Reservoir, La. and Tex.	Cypress Creek	810,000	660,000	Inactive	11,200,000	FC
*Texarkana Reservoir, Tex.	Sulphur River	2,654,300	2,509,000	In Operation	36,002,000	FC, WS(3)
*Bayou Pierre in the vicinity of Shreveport, La.	Bayou Pierre	-	-	Complete	243,336	FC
*Maniece Bayou, Ark.	Maniece and Field Bayous	-	-	Under Const.	1,179,500	FC
*McKinney Bayou, Tex. and Ark.	McKinney Bayou	-	-	Complete(4)	1,456,700	FC
*Red River below Denison Dam, levees and bank stabilization	Red River	-	-	Under Const.	15,800,000	FC
*Bayou Pierre, La.	Bayou Pierre	-	-	Complete	299,529	FC
*Wallace Lake Reservoir, La.	Cypress Bayou	96,100	88,300	Complete	1,219,371	FC
*Bayou Bodcau Reservoir, La.	Bayou Bodcau	357,000	357,000	Complete	4,220,740	FC
*Posten Bayou, Ark. and La.	Posten Bayou	-	-	Inactive	560,000	FC
*Lower Red River Levees (Feature of Mississippi River and Tributaries Project)	Red River	-	-	Under Const.	8,990,000	FC
*Hempstead County Levee Dist. No. 1, Ark.	Red River	-	-	Complete	88,006	FC
*Red River Parish, La.	Red River	-	-	Complete	149,435	FC
*Natchitoches Parish, La.	Red River	-	-	Complete	1,529,927	FC
*Grant Parish below Colfax, La.	Red River	-	-	Complete	38,809	FC
*Aloha-Rigolette Area, Grant and Rapides Parishes, La.	Bayou Rigolette	-	-	Complete	1,653,237	FC
*Pineville, Red River, La.	Red River	-	-	Complete	232,426	FC
*Colfax, Grant Parish, La.	Red River	-	-	Complete	70,348	FC
*Saline Point, La.	Red River	-	-	Complete	124,111	FC
*Red River in vicinity of Shreveport, La.	Red River	-	-	Complete	3,908,000	FC
*Black Bayou Reservoir, La.	Black Bayou	33,800	33,800	Inactive	714,000	FC
*Bayou Bodcau, Red Chute and Loggy Bayou, La.	Bayou Bodcau, Red Chute and Loggy Bayous	-	-	Complete	319,200	FC
Lower Red River, La.(5)	Red River	-	-	Under Const.	8,990,000	FC
Total, U. S. Army Engineer District, New Orleans					$145,489,675	

(1)FC - Flood Control; WS - Water Supply.
(2)Channels portion under construction, reservoir not started.
(3)To be provided by conversion of flood control storage space after completion of Cooper Reservoir.
(4)Modification authorized by Flood Control Act of 1960 is inactive.
(5)Feature of the Mississippi River and Tributaries project.
* Feature of Red River below Denison Dam project.

TABLE 3

EXISTING, UNDER CONSTRUCTION, AND AUTHORIZED PROJECTS
U. S. ARMY ENGINEER DISTRICT, TULSA

Project	Stream	Total Storage (ac-ft)	Flood Control Storage (ac-ft)	Status	Estimated Cost	Purpose(1)
*Boswell	Boggy Creek	1,130,000	1,100,000	Restudy	$ 24,100,000	FC, R, F&WL
*Clayton	Jackfork Creek	290,500	104,000	Authorized	14,000,000	FC, R, F&WL
*Tuskahoma	Kiamichi River	374,000	138,600	Authorized	17,600,000	FC, R, F&WL
*Hugo	Kiamichi River	849,500	809,500	Under Const.	30,700,000	FC, R, F&WL, WQ
*Pine Creek	Little River	465,800	388,000	Under Const.	21,200,000	FC, WS, WQ
*Lukfata	Glover Creek	206,600	172,000	Authorized	13,400,000	FC, WS, WQ
*Broken Bow	Mt. Fork River	1,368,800	450,000	Under Const.	39,600,000	FC, P, WS, WQ
*De Queen	Rolling Fork	136,100	101,200	Under Const.	11,500,000	FC, WS, WQ
*Gillham	Cossatot River	221,800	188,700	Under Const.	14,800,000	FC, WS, WQ
*Dierks	Saline River	80,000	66,000	Under Const.	10,600,000	FC, WS
*Millwood	Little River	1,858,000	1,651,400	Complete	43,077,000	FC, WS
Pat Mayse	Sanders Creek	189,100	64,600	Under Const.	7,700,000	FC, WS
Big Pine	Big Pine Creek	138,600	54,700	Authorized	9,200,000	FC, WS
*Bank Stabilization	Red River	-	-	Complete	222,105(2)	FC
*Walnut Bayou	Walnut Bayou	-	-	Complete	317,675(2)	FC
Total, U. S. Army Engineer District, Tulsa					$258,016,780	

(1)FC - Flood Control; P - Hydroelectric Power; WS - Water Supply; WQ - Water Quality Control; R - Recreation; F&WL - Fish and Wildlife.
(2)Actual cost.
* Part of Red River below Denison Dam project.

(3) The Big Pine Reservoir, Texas, also was authorized by the Flood Control Act of October 23, 1962. It is to have a total storage capacity of 138,600 acre-feet, with 54,700 acre-feet allocated to flood control. As of June 30, 1967, construction had not been initiated. Estimated total cost of the project is $9,200,000.

(4) The Lower Red River, Louisiana (South Bank Red River Levees), a feature of the Mississippi River and Tributaries project, consists of a levee 59.8 miles long from Hotwells, Louisiana, to Moncla, Louisiana, and bank protection works on the south bank at Alexandria, Louisiana, and other critical locations. This work was authorized by the Flood Control Act of May 15, 1928. Total estimated cost is $8,990,000.

b. Other Federal projects. The Soil Conservation Service, U. S. Department of Agriculture, had 13 watershed projects authorized for construction in the basin prior to December 31, 1962. An additional 13 watershed projects had been approved through March 1968. These projects, authorized by Public Law 566, as amended, include one or more of the following purposes: flood control, watershed protection, drainage, municipal and industrial water supply, water quality, irrigation, and recreation. Pertinent data on the projects are given in table 4. In addition, the U. S. Forest Service has constructed a number of impoundments for recreation.

c. Local levee and bank protection projects. Local interests have constructed more than 400 miles of main stem and backwater levees along both banks of Red River between Index, Arkansas, and Lake Long, Louisiana. Local political groups, railroads, and other private interests have constructed protection works where caving banks threatened developed lands and improvements. Such work was undertaken as early as 1896. After 1914, local interests constructed bank protection works at 93 locations at and below Index, Arkansas. Structures include board mattresses, pile dikes, retards, rock and brush dikes, training walls and pipe tetrahedrons, and fascine boxes. The value of these works at current prices is around $200 million.

d. Other improvements. In addition to the levees and bank protection works along the main stem of Red River, local interests have constructed numerous improvement works throughout the basin for flood control, water supply, recreation, and other purposes. Most of these works are of minor scope and their beneficial effects accrue to areas of rather limited extent.

TABLE 4

SOIL CONSERVATION SERVICE AUTHORIZED WATERSHED PROJECT STRUCTURAL DATA

Tributary Basin and CNI Watershed	Watershed Area	Drainage Area Controlled	Floodwater Retarding Structures	Channel Improvements[1]	Storage: Detention	Storage: Sediment	Storage: Other[2]	Surface Area Permanent Pool[3]
	(sq.mi.)	(sq.mi.)	(number)	(miles)	- -	(ac.ft.)	- -	(acres)
Intervening Areas - Texas								
3-21	73.1	40.7	15	-	14,324	2,863	-	482
Total	73.1	40.7	15	-	14,324	2,863	-	482
Intervening Areas - Arkansas and Oklahoma								
3-36	46.2	23.6	9	4.5FP & 15.0MP	8,474	790	-	191
Total	46.2	23.6	9	19.5	8,474	790	-	191
Blue River								
3-23a	317.3	219.3	74	-	57,929	7,236	-	1,517
Total	317.3	219.3	74	-	57,929	7,236	-	1,517
Boggy Creek								
3h1-4	78.2	51.9	14	-	13,907	1,996	-	14
3h1-5	168.7	117.0	43	-	34,726	3,905	-	891
3h1-6	253.8	178.2	54	-	54,328	5,611	-	1,065
3h2-5	36.9	29.7	3	-	10,441	1,061	3,000M	535
Total	537.6	376.8	114	-	113,402	12,573	3,000M	2,505
Sulphur River								
3k-8	39.1	16.9	12	-	5,214	662	1,118M	340
3k-13	49.5	19.0	14	-	6,233	1,119	-	290
Total	88.6	35.9	26	-	11,447	1,781	1,118M	630
Loggy Bayou								
3m2-4	8.7	4.5	3	-	1,779	1,534	710M 595FW	249
Total	8.7	4.5	3	-	1,779	1,534	1,305	249
Bayou Pierre								
3n-3	90.0	44.3	22	2.9FP	14,406	2,153	-	547
Total	90.0	44.3	22	2.9	14,406	2,153	-	547
Bayou Rapides								
3-68 and 10-17	154.5	-	1	20.0ID	-	652	18,573I 5,775R	1,775[4]
Total	154.5	-	1	20.0	-	652	24,348	1,775
Grand Total	1,316.0	745.1	264	42.4	221,761	29,582	29,771	7,896

1/ Abbreviations: FP-Flood Prevention; MP-Multiple-purpose; ID-Irrigation delivery system.
2/ Abbreviations: M-Municipal; FW-Fish & Wildlife; I-Irrigation; R-Recreation.
3/ Total surface area at principal spillway elevation.
4/ Supplemental work plan data included.

CHAPTER II - GENERAL CRITERIA, GUIDELINES AND PROCEDURES

7. GENERAL

As used in this appendix, flood control and major drainage needs are defined as areas of land which are now experiencing or which will experience, by 2080, economic losses due to flooding and inadequate drainage. Analyses herein of basin needs are based on estimated conditions assuming all presently authorized improvements are in place and operating effectively except the Overton-Red River Waterway, and the inactive Mooringsport and Black Bayou Reservoirs.

Major losses result from headwater flooding along the main stem of Red River and in the flood plains of the tributary streams; backwater flooding due to high stages on the Red River; and drainage water impounded by local levee loops or from combinations of the above. An additional flood problem with serious consequences results from bank caving along the river. This problem has been treated in detail in the "Interim Report on Navigation and Bank Stabilization, Red River below Denison Dam," dated March 1966, and will not be considered further in this appendix.

Because of the rural character of the basin, the principal flood damages are agricultural losses due to reduced crop yields or total destruction of crops, and damages to pasture and livestock. Other losses include damage to roads, bridges, farm improvements, urban developments, oilfield structures, railroads, and utility lines. The estimated average annual damages over the study period in upstream watersheds and downstream flood plains, considering future land conversions and increased crop yields that will occur without the installation of additional flood control projects, amount to about $11.6 million. Of the total damages, about $1.0 million is in the adjacent areas studied by the SCS. Additional data relating to damages in upstream watersheds are included in appendix V.

The threat of additional losses has discouraged, to a marked degree, utilization of the potentially highly productive alluvial bottom land in the area. Thus, these lands should be a prime source of the substantial increases in agricultural production necessary to meet future food demands. Future domestic demands and normal export trade will ultimately necessitate full utilization of productive bottom lands in this area.

It should be recognized that not all flood damages are preventable by structural measures. All too frequently construction of flood control works has served to spur unwise use of flood plains and thus contributed to a growing toll. More consideration of the contribution which can be made by nonstructural measures such as proper regulation of developments in flood prone areas and flood proofing is indicated. This is not to say that the relationship between structural and nonstructural measures in the reduction of flood damages is an "either - or" one. In fact, the contributions of both will most likely be maximized by intelligently combining the two.

Basic agricultural needs were developed by the U. S. Department of Agriculture and are presented in appendix V. Projections of needs

in each subbasin were influenced by stream locations, flood problems, and soil conditions. A summary of the flood control and major drainage needs in the downstream flood plains of the basin is shown in table 5.

Basin information on flood damages was obtained through field investigations, interviews, and correspondence with individual farmers, businessmen, civic associations, and governmental agencies in the area. A detailed analysis of flood problems along the main stem of the Red River and each of its major tributaries is presented in paragraph 9.

8. PROCEDURES UTILIZED IN SYNTHESIZING AND EVALUATING ALTERNATIVE SOLUTIONS

Alternative solutions responsive to the needs in each subbasin were developed based on the consideration of all practicable alternatives. The economics of each alternative was evaluated by comparing estimates of annual costs and annual benefits. Estimates of benefits were based on the annual flood damages prevented and enhancements that would be realized from reduced flood hazards and improved drainage. Where applicable, appropriate weight was given to intangible and secondary benefits. Coverage in this appendix is limited to general information concerning individual flood problems and possible solutions. Alternatives most responsive to current and long-range needs, and the basis for selection of such alternatives are considered in detail in appendix XV, "Plan Formulation."

CHAPTER III - FLOOD PROBLEMS AND POSSIBLE SOLUTIONS

9. MAIN STEM OF RED RIVER

a. The total unprotected alluvial flood plain of the Red River consists of about 1,400,000 acres. With all authorized improvements in place approximately 850,000 acres (480,000 cleared land) will receive protection from Red River overflow. Of the remaining 550,000 acres, batture land as well as areas landside of existing levees, 300,000 acres have been cleared. Flood damages in this remaining area are predominantly agricultural with some losses to structural features in the flood plain. Increased demand for food production along with the gradual retirement of marginally productive lands will necessitate protecting all of the highly fertile lands along the main stem. By 2080, an estimated 130,000 acres of existing woodland will be cleared, making a total of 430,000 acres which will require additional flood protection.

b. A general lowering of the flow line in the river could provide the required protection. Investigations were made to determine the feasibility of lowering the flow line. The only practicable means of accomplishing significant lowerings would be by the construction of large detention reservoirs on tributary streams or the main stem. Such improvements were found to lack economic justification at this

TABLE 5

FLOOD CONTROL AND MAJOR DRAINAGE NEEDS
IN DOWNSTREAM FLOOD PLAINS

Tributary Basin	Present Needs (acres)	Estimated Additional Needs by 2080 (acres)	Total Needs by 2080 (acres)
Red River (Main Stem), Ark-La-Okla-Tex	300,000	130,000	430,000
Blue River, Okla.	11,800	4,800	16,600
Boggy Creek, Okla.	7,100	4,700	11,800
Kiamichi River, Okla.	1,600	1,000	2,600
Little River, Ark-Okla.	5,600	10,000	15,600
Island Bayou, Okla.	5,800	2,100	7,900
Brown Creek, Okla.	2,200	1,500	3,700
Choctaw Creek, Tex.	7,100	800	7,900
Bois d'Arc Creek, Tex.	9,800	6,300	16,100
Colliers Creek, Tex.	250	250	500
Pecan Bayou, Tex.	2,300	1,500	3,800
Mill and N. Mill Creeks	3,200	2,100	5,300
Mud Creek, Tex.	1,200	800	2,000
Red Bayou, Tex.	800	500	1,300
Barkman Creek, Tex.	2,800	1,000	3,800
Hempstead Levee Dist. No. 1, Ark.	1,000	300	1,300
Bois d'Arc Creek, Ark.	1,000	2,000	3,000
Maniece Bayou, Ark.	5,500	-	5,500
McKinney Bayou, Tex-Ark.	42,000	17,000	59,000
Sulphur River Basin, Tex-Ark.			
a. Streams above Lake Texarkana, Tex.	40,000	25,000	65,000
b. Days Creek (Texarkana), Tex-Ark.	2,200	700	2,900
Posten Bayou, Ark-La.	12,500	2,700	15,200
Cypress Creek Basin, Tex-Ark-La.			
a. Kelly-Black Bayous, Tex-Ark-La.	8,600	900	9,500
b. Frazier Creek, Tex.	1,500	1,000	2,500
c. Black Cypress Creek, Tex.	400	600	1,000
d. Cypress (Big) Creek, Tex.	4,000	3,200	7,200
e. Little Cypress Creek, Tex.	6,500	8,000	14,500
f. Twelvemile Bayou, La.	3,600	3,500	7,100
g. Middle Bayou and McCain Creek, La.	1,500	1,500	3,000
Loggy Bayou Basin, Ark-La.			
a. Bayou Bodcau, Ark-La.	8,000	5,000	13,000
b. Bayou Dorcheat, Ark-La.	14,200	2,500	16,700
Bayou Nicholas, La.	-	200	200
Campti-Clarence Area, La.	1,000	2,000	3,000
Cane River-Kisatchie Bayou, La.	18,000	8,500	26,500
Bayou Rapides, La.	10,000	6,000	16,000
Bayous Du Grappe-Rigolette, La.	16,000	9,000	25,000
Total (acres)	559,050	266,950	826,000

time. Bank stabilization works are a practical means to bring part of the threatened lands in the flood plain back into agricultural production. Furthermore, these works would eliminate future levee setbacks which remove some of the best lands from production.

c. Investigations were extended to determine the feasibility of lowering the flood line at some time in the future. Tributary reservoir storage proved to be the most practicable solution to the long-term flood problems. It was concluded that such works, at an estimated cost of about $200 million, would be economically justified for construction during the period 2010-2030. The construction should be spread about evenly over the 20-year period. This program would eliminate essentially all flood problems along the main stem and, in addition, would significantly reduce damages along many of the tributary streams.

d. Since a general lowering of the flow line is impracticable at the present time, preliminary investigations were made for local protection projects at various locations along the main stem. Three areas along the main stem were found to suffer backwater flooding of sufficient magnitude to warrant detailed investigation of local protection projects. The results of these investigations are given below.

(1) Bayou Pierre, Louisiana. Average annual damages from backwater flooding along Bayou Pierre are $34,800, of which $29,200 are crop damages and $5,600 are losses to structural improvements. Ring levees around the area with drainage structures to evacuate local runoff were found to be the most suitable flood control solution. The annual cost of the plan is estimated to be about $190,000. The plan would provide annual benefits of about $31,000 and is, therefore, not economically justified for inclusion in the early-action plan of development. However, it is likely that the future demand for agricultural products will support development in this area by about 2015. The improvements should, therefore, be included in the long-range plan. By about 2055, further incremental development will probably justify the installation of pumping facilities for removing ponded runoff.

(2) Bayou Jean de Jean, Louisiana. A plan was developed that would prevent 86 percent ($6,000) of the existing flood damages as well as provide about $10,000 of increased land utilization benefits. The major elements of the plan are loop levees and pumping facilities. The annual cost of the improvements was estimated to be more than twice the annual benefits; hence, these features were not included in the proposed basin plan.

(3) Black Lake-Saline Bayous, Louisiana. Major features of the most suitable plan include levees and drainage structures. Annual flood damages would be reduced from the existing $5,000 to

about $1,000. Increased land utilization benefits of $4,000 would also accrue from the proposed plan. These benefits are not sufficient to justify estimated annual costs of $21,000. Future development in this area sufficient to warrant implementation of the plan is considered unlikely.

(4) East Point, Louisiana. Approximately 2,000 acres of fertile, alluvial bottom land, mostly in woods, is presently subject to overflow by ponding of intercepted runoff during recurring high stages on Red River. Anticipated woodland conversions plus intensified agricultural cultivation by year 2020 will probably support the installation of pumping facilities at a cost of about $1,000,000.

10. TRIBUTARIES

a. Choctaw Creek, Texas. This stream drains 263 square miles and flows into the Red River about 16 miles below Denison Dam. An estimated 7,100 cleared acres are currently subject to flooding. Little additional development is expected in this basin. The 2080 flood control requirement is estimated to be about 7,900 acres.

A multiple-purpose reservoir and a channel improvement project were considered as means of reducing flooding on the 7,100 acres of land presently needing additional flood protection. Neither project was found to be economically justified. An SCS plan consisting of upstream reservoirs combined with channel improvement produced the greatest benefits and is included in the early-action program.

b. Brown Creek, Oklahoma. Brown Creek, which overflows its banks an average of twice a year, drains only about 20 square miles and flows directly into the Red River. An estimated 2,200 acres are subject to frequent flooding and require additional protection. The future flood control requirement is estimated to be 3,700 acres.

A channel improvement project for Brown Creek was authorized in 1955, but the authorization expired in 1962 due to lack of local cooperation. This project consisted of diverting Brown Creek from mile 6.4 to the Red River and improving an existing drainage ditch. In the current study, a plan for improving the channel generally along the existing stream alignment was investigated. First cost of this plan would be $1,060,000 and the B/C ratio is 1.4. Because of continued lack of local support, however, the Brown Creek channel improvement project has been placed in the long-range plan of development.

c. Island Bayou, Oklahoma. Under existing conditions, 5,800 acres of cleared land in the lower reaches are subject to headwater overflow. Expanded agricultural activity in the basin will increase this need to about 7,900 acres by 2080. Channel improvement along Island Bayou and the provision of flood control storage in a multiple-purpose reservoir were determined to be the only feasible means of providing flood protection. It was found that, with the latter approach, a much higher degree of protection could be achieved.

The flood control storage would be included in the proposed Albany Reservoir, a multiple-purpose project with a first cost of $11,000,000 and annual charges of $486,300. This project would yield benefits of $656,700, of which $95,700 are for flood control. Detailed formulation of the plan for this reservoir is shown in appendix XV, "Plan Formulation."

d. Blue River, Oklahoma. The Blue River watershed is located in southeastern Oklahoma and is approximately 80 miles long with a maximum width of about 14 miles near Durant, Oklahoma. Blue River rises in the Arbuckle Mountains region in Pontotoc County, Oklahoma, and flows in a southeasterly direction to enter the Red River about 56 river miles below Denison Dam. The river is comparatively narrow, and the flood plain in the lower Blue River Basin contains approximately 20,000 acres, about 11,800 acres of which are in cultivation. Roads, highways, and railroads are the major improvements subject to inundation in the flood plain. No levee systems exist, and flood damage is usually small since the duration of overflow is short. The estimated 2080 flood control needs are 16,600 acres, including the present need of 11,800 acres.

Floods on the Blue River contribute to flooding along the Red River from the mouth of Blue River to Fulton, Arkansas. The flood of record occurred in February 1938.

The SCS has an authorized plan of development for the upper Blue River; therefore, the Corps of Engineers studies were oriented toward the lower Blue River Basin. Channel improvement was considered, but preliminary cost studies indicated that reservoir storage would be more economical. In addition, flood control storage at Durant Reservoir will operate to reduce flood flows on the main stem of Red River.

A combined plan, comprising a multiple-purpose reservoir on Blue River with flood control storage and 13 flood retarding structures and other upstream watershed improvements (SCS), was developed. The combined plan, with a first cost of $22,571,250 and annual charges of $964,430 would yield benefits of $1,368,450 of which $479,500 are for flood control. Detailed data on this plan are included in appendix XV, "Plan Formulation."

e. Bois d'Arc Creek, Texas. This stream is small and choked with brush and timber except in its lower reach. Near the middle of the basin, the channel is poorly defined and meanders through a broad, flat flood plain. Population in the flood plain is sparse; however, crop production is high. A number of roads, highways, and railroads are subject to flood damage. Extensive flooding affects about 16,100 acres (9,800 cleared) in the lower two-thirds of the basin. By 2080, additional flood protection will probably be needed on all 16,100 acres of land presently subject to flooding.

Channel improvement for flood control was considered in preliminary planning, but was found to lack economic justification. A plan comprised of a flood control reservoir on Bois d'Arc Creek combined with the SCS channel improvements and system of detention reservoirs, was determined to be the most practicable solution to the flood problems in this basin. The combined plan would have a total first cost of $21,909,520 and annual charges of $961,200. The total annual benefits would be $1,399,440, of which $665,230 are for flood control. Detailed data on this plan are contained in appendix XV, "Plan Formulation."

f. Boggy Creek, Oklahoma. Boggy Creek enters Red River approximately 83 river miles downstream from Denison Dam. The major streams tributary to Boggy Creek are Muddy Boggy and Clear Boggy Creeks, both of which rise in the vicinity of Ada, Oklahoma. The total watershed is composed of approximately 60 percent gently rolling hill country and 40 percent steep mountainous country. Practically all of the mountain area and 60 percent of the hill area is timberland. The flood plain is sparsely populated with no urban areas. The valleys of Muddy Boggy and Clear Boggy Creeks have a total of approximately 20,000 acres (7,100 cleared) subject to flooding. Expected development in the area will increase the flood control needs to about 11,800 acres of cleared lands by 2080. Preliminary investigations demonstrated that a multiple-purpose reservoir with flood control storage on Muddy Boggy Creek in combination with detention reservoirs and land treatment measures is feasible for inclusion in the early-action program. This plan would have a first cost of $16,366,000, and annual charges of $710,230. The total annual benefits would be $1,366,800, of which $472,700 are for flood control. Investigations also demonstrated that a multiple-purpose reservoir on McGee Creek, containing flood control storage, is also feasible for inclusion in the early-action program. This plan would have a first cost of $15,600,000, and annual charges of $682,000. The total benefits would be $733,000, of which $107,500 are for flood control. Details of the plan are given in appendix XV, "Plan Formulation."

Below the authorized Boswell Reservoir about 600 acres of land remain subject to flooding. However, because of the high degree of protection which Boswell Reservoir will afford, residual annual damages will be negligible. Therefore, no flood control projects were considered for Boggy Creek below the authorized reservoir.

Reservoirs upstream of Boswell Reservoir will be required to develop the full water supply potential of the stream. However, additional major reservoir projects, except Parker and McGee Creek Reservoirs, would not be justified until such time as flood control and water supply needs increase. At that time, a study of the reallocation of storages in Boswell Reservoir would be in order.

Studies to date indicate that stage development of the Boggy Creek Basin is feasible. Possible improvements to provide for

protection from 50-year floodflows and full development of the streams' yield include:

Damsite	Stream	Estimated First Cost
Tupelo	Clear Boggy Creek	$18,500,000
Chickasaw	Chickasaw Creek	3,979,000

g. Kiamichi River, Oklahoma. The upper 70 percent of this watershed is mountainous and covered with a heavy growth of timber. The lower 30 percent is rolling hill country, about 23 percent of which is cleared and cultivated. With the authorized Tuskahoma, Clayton, and Hugo Reservoirs in place, about 1,600 acres of cleared land will remain subject to flooding. About 1,000 more acres are expected to be brought into agricultural production by 2080, making a total long-term need for flood protection of 2,600 acres.

Three additional multiple-purpose reservoirs in the basin were considered in the studies. These were the Buck Creek site on Buck Creek, the Finley site on Cedar Creek, and the Kellond site on Tenmile Creek. A tabulation of costs and benefits is shown below.

	Buck Creek Site	Finley Site	Kellond Site
First cost	$17,200,000	$12,600,000	$8,600,000
Annual charges	684,000	512,000	356,000
Estimated annual benefits	325,000	310,000	230,000
Benefit-cost ratio	0.5	0.6	0.7

Although none of the three reservoirs were determined to be economically feasible under existing economic conditions, significant residual flood problems exist, and it is considered that construction will be justified in the future on the basis of projected development.

Possible solutions to future flood problems include reallocation of Hugo Reservoir storage between flood control and conservation storage with no loss of flood control benefits. Similar reallocations could be made at the authorized Clayton and Tuskahoma Reservoirs with slight increases in the authorized height of the dams.

h. Little River and Tributaries, Arkansas-Oklahoma. Floods occur on Little River and tributaries throughout the year. On the tributaries, they occur as flash floods of from 1 to 3-day duration; in the lower reaches of Little River, they are of longer duration due to limited channel capacity and sluggishness of the stream. In 1945, the river overflowed its banks below Horatio, Arkansas, for

1 1/2 months and in 1957 the river overflowed its banks 73 days during a period of 3 months.

A system of seven reservoirs is authorized in the Little River Basin for flood protection on the Little River and on the Red River below Fulton, Arkansas: Pine Creek on Little River; Lukfata on Glover Creek; Broken Bow on Mountain Fork River; DeQueen on Rolling Fork River; Gillham on Cossatot River; Dierks on Saline River; and Millwood on Little River.

Total overflow area along Little River is about 250,000 acres, less than 10 percent of which is cleared. There are no large urban areas in the basin and residual flood damages are small. With all authorized reservoirs in place, about 5,600 cleared acres will remain subject to flooding. By 2080, it is estimated that a total of 15,600 acres will have been cleared and will require additional flood protection.

The following multiple-purpose reservoirs were studied as possible means for alleviating flood problems on the 5,600 acres:

Reservoir	Stream	Estimated First Cost $	Estimated Annual Charges $	Estimated Annual Benefits $	B/C Ratio
Caney Mt.	Little R.	13,900,000	551,000	Less than costs	Less than 1
Hartley	Cossatot R.	14,500,000	575,000	Less than costs	Less than 1
Horatio	Little R.	69,500,000	2,641,000	Less than costs	Less than 1
Mineral Springs	Mine Creek	24,700,000	982,000	Less than costs	Less than 1
Mena	Mount.Fork R.	7,030,000	329,000	365,000	1.1
Sherwood	Mount.Fork R.	154,400,000	8,884,900	14,163,100	1.6

Reconnaissance scope studies were sufficient to indicate an obvious lack of justification for the first four projects listed. Mena Reservoir was studied in detail, but lacked local support for the water supply storage which was necessary for overall justification. Horatio Reservoir was studied in detail, but is not included in the plan of improvement because of the lack of public support. Sherwood Reservoir, which would have storage for flood control and hydropower, is included in the early-action plan of development. Results of detailed studies of this reservoir, including costs and benefits, are presented in appendix XV, "Plan Formulation."

The Caney Mountain, Hartley, and Mena projects offer excellent opportunities for future development and are included in the long-range plan.

i. Colliers Creek, Texas. This stream drains an area of about 36 square miles. About 250 acres of cultivated land are subject to flooding at the present time. Anticipated woodland conversion of another 250 acres will result in a total of 500 acres requiring flood protection by the year 2080.

A multiple-purpose project, designated the Acworth Reservoir, was investigated as a possible solution to the flood problem in the area. This reservoir, located at river mile 3.9, would have a first cost of $3,500,000 and an annual charge of $168,500. Benefits are less than the cost at this time, but the project is considered feasible for inclusion in the long-range plan of development.

j. Pecan Bayou, Texas. This stream flows in a generally easterly direction to its confluence with the Red River south of Idabel, Oklahoma. Presently, about 2,300 acres of cultivated land in the watershed are subject to flooding. An increase in cultivated land of about 1,500 acres is expected during the 100-year study period; hence, 3,800 acres will require additional flood protection by 2080.

Studies of means to relieve flooding on the 2,300 acres of cleared land included a reservoir and a channel improvement project. The reservoir, designated Madras, with the damsite at river mile 20.4, would be multiple-purpose, have a first cost of $12,200,000, annual charges of $491,000, and a benefit-cost ratio of 1.1. The Texas Water Development Board has proposed a reservoir in this area as part of the Texas Water Plan. As envisioned by the Board, the reservoir, with the damsite at river mile 23, would have a conservation capacity of 369,780 acre-feet and would regulate diversions from Red River and flows in the Pecan Bayou watershed. Releases from the Pecan Bayou Reservoir would flow through the Red-Sulphur divide by means of a 15,000-foot long gravity flow tunnel, and discharge into a 9 1/2-mile channel to the proposed Naples Reservoir.

k. Mill and North Mill Creeks, Texas. These creeks are downstream of Pecan Bayou and together drain 94 square miles. About 3,200 acres of cleared land along these streams are presently subject to headwater flooding. Another 2,100 acres are expected to be cleared by 2080 resulting in a future need for flood protection of 5,300 acres. Storage reservoirs and channel improvement plans were considered but all were found to lack economic justification at this time. Approximately 1,700 acres of farm land in the Mill Creek Basin is subjected to flood damage. An estimated 2,800 acres total will be in cultivation by year 2080. The Pine Springs Reservoir site at river mile 12.7, included in the long-range plan of development, would cost $3,100,000 and offers potential for flood control, water supply, and recreation. The water is of good to excellent quality.

l. Mud Creek, Texas. This channel is small and fairly well defined. The lower reaches are choked with brush and timber. Population density in this basin is light with no urban areas involved. About 1,200 acres of cultivated land are subject to flooding at this time. Agricultural demands are expected to result in conversion of about 800 acres of woodland to cultivated land over the 100-year study period. However, flood relief from measures on Mud Creek would not be realized due to backwater from the Red River. No plans for additional flood protection, therefore, are proposed for this basin.

m. Red Bayou, Texas. This small stream drains a 31-square mile area directly into the Red River. Frequent flooding occurs along the stream because of the limited size of the channel and relatively flat channel slopes. The 2080 need for additional flood protection is estimated to be 1,300 acres. This amount includes 800 cleared acres presently needing protection plus an anticipated increase of 500 acres over the study period.

A multiple-purpose reservoir was studied. This project, known as the New Zion Reservoir, would control floods on the lower reach of Red Bayou and provide water supply for the city of New Boston. First cost of the reservoir would be $5,300,000 with annual charges of $233,000 (giving a benefit-cost ratio of 1.0). This project was not included in the basin early-action plan because the water supply needs of the area could be met from a more favorable alternative, Liberty Hill Reservoir on nearby Mud Creek, and flood control could not be justified separately. It is considered that this project will be needed late in the 100-year study period and it is included in the long-range plan.

n. Barkman Creek, Texas. About 4,800 acres of bottom lands, of which some 2,800 acres are cleared, are subject to headwater flooding along Barkman Creek. The portion of the watershed outside the fertile alluvial valley comprises hilly uplands drained by short, intermittent streams. Aside from headwater inundation, this area is also subject to infrequent backwater overflow from the Red River. Damages caused by flooding are primarily agricultural and consist of losses to crops, pasture, and livestock. Excessive frequency of flooding, especially during periods of moderately high stages on Red River, has restricted land utilization. Comprised of Red River alluvial bottom land, the soils are very fertile and highly productive. Woodland conversions and higher land usage would follow the installation of flood control and attendant drainage works. Allowing for areas not suitable for agricultural production, additional flood control will be needed on the 2,800 acres of presently cleared lands plus an estimated 1,000 acres of land which will be brought into production by 2080.

The Soil Conservation Service, Department of Agriculture, has developed a plan of channel improvement that will alleviate the flood problems in this watershed. This plan is presented in appendix V, "Upstream Watershed Protection, Use, Management, and Development."

o. Hempstead Levee District No. 1, Arkansas. The area subject to overflow encompasses about 2,100 acres of Red River bottom land, of which about 1,000 acres are cleared. The cleared land is used for crops and pasture, both improved and native. Flooding of this area is caused by excessive rainfall ponding when stages of the Red River are at such heights as to preclude the opening of the gated drainage structures. An estimated 30 percent or 300 acres of the present woodland will be converted to either crop or pasture use by the year 2080. Therefore, the total future need for flood control would be 1,300 acres.

Although there are some flood control needs in this area, hydraulic studies indicated that gravity drainage is feasible for all but the greatest floods and the installation of pumps to evacuate ponded water could not be justified.

p. Bois d' Arc Creek, Arkansas. Bottom lands along Bois d' Arc Creek comprise a wide, relatively flat wooded area. The channel, which is of insufficient size and capacity, is choked by heavy growth and meanders throughout the valley. High rates of runoff from surrounding hills create serious flood problems over a large portion of this basin several times each year. Approximately 13,000 acres (1,000 cleared) below U. S. Highway 67 are subject to flooding from headwater overflow and from backwater during high stages along Red River. Because of a lack of improvements in the overflow area and the small acreage devoted to agricultural production, the average annual losses are small. These losses include damage to crops and pasture stands, costs of moving cattle, and disruption of local traffic. In addition to the excessive frequency and duration of flooding, other reasons for the lack of agricultural development in the upper reach of the basin between U. S. Highway 67 and the Red River alluvial bottom are low soil fertility and the high cost of land conversion. In the lower reach, where the stream flows through the Red River bottoms (about 3,000 acres total), development has been discouraged by the severity of the flood problem.

Total flood control needs, including the existing 1,000 acres of cleared lands plus some 2,000 acres of additional clearing anticipated within the study period, amount to 3,000 acres. This acreage is about equally divided between the upper and lower reaches.

Two plans were developed to reduce the average annual flood damages which currently amount to $14,000. Channel improvements were found to provide annual benefits of $27,000, including increased land

utilization benefits of $23,000. Construction of levees would alleviate about $5,000 of the flood damages but would provide no increased land utilization. The annual cost of the channel improvement works is $88,000, while that for the levee plan is $59,000. Construction of neither plan is justified at this time.

q. Maniece Bayou, Arkansas. Maniece Bayou is a left bank tributary of the Red River which meanders along the main stem flood plain. The upper reaches are protected from Red River floods by a levee. Agriculture is the predominant economic activity of the basin; however, some oilfield activity exists near the center of the area. Flood losses are experienced mainly on agricultural lands, about $5,000 annually, with some minor damages to the petroleum industry and the local road system.

A channel enlargement project is presently under construction which is designed to confine a 10-year frequency flood within the bayou banks. With this improvement in place, the area remaining subject to infrequent headwater flooding will encompass 10,000 acres, of which 5,500 acres are cleared. The lower portion of the basin, about 16,000 acres, of which 6,000 acres are cleared, is subject to backwater inundation from the Red River. Needs of this lower area are discussed in the paragraph on the Red River Main Stem.

No additional clearing is expected in the upstream area so the future need for flood protection is the same as the present need, i.e., 5,500 acres. A channel improvement plan was designed to eliminate damages in the upper area. Since the presently improved channel of Maniece Bayou is designed to confine a 10-year frequency flood, no land enhancement would result from further improvement. The annual cost of the plan is estimated to be about $30,000. Since only about $5,000 of benefits would accrue to this improvement, the plan is not now economically feasible, nor is the prognosis for it sufficiently favorable to warrant placing it in the long-range plan.

r. McKinney Bayou, Texas-Arkansas. Some 69,000 acres of Red River bottom lands in Texas and Arkansas, 42,000 of which are cleared, are subject to headwater overflow along McKinney Bayou and its tributaries. The completed part of the Federal flood control project offers partial protection to an estimated 17,400 acres of these cleared lands by means of channel and levee works along the main stream. Residual flood damages amount to $185,000 annually. Threats of inundation from Red River have been eliminated by other Federal and local projects.

Major losses in the basin are largely agricultural in nature. Aggressive land clearing programs have been conducted over the past 10 years in this vicinity and this trend is expected to continue. Of the 69,000 acres in the problem area, needs for flood

damage reduction (after making allowances for lands within the existing floodway, necessary sump areas and other lands unsuitable for agricultural purposes) are estimated to be 59,000 acres. These needs include the 42,000 acres presently cleared plus an estimated 17,000 acres of land for future development. The estimate is based on the conclusion that increased demand for food production, as a result of population increases, will necessitate the use of all potentially productive Red River bottom lands.

Plans involving enlargement of the sole existing outlet, as well as construction of new outlet channels, were studied. The most favorable plan was found to be enlargement of McKinney Bayou, construction of two new outlets, and upstream watershed improvements. The project would have a first cost of $6,555,000. The annual costs and benefits of the plan are $429,200 and $833,000, respectively. Details of the analysis made to determine the optimum plan for this basin are contained in appendix XV, "Plan Formulation." The proposed improvement will protect about 30,000 of the 42,000 acres currently needing flood relief. The total future flood control need subsequent to construction of the proposed plan will consist of the 12,000 acres of unprotected existing development, plus the estimated increase over the study period (17,000 acres), or a total of about 29,000 acres. Future lowering of stages on the Red River will provide partial relief to some of this land. Further flood control could be achieved by enlarging the existing outlet, constructing additional auxiliary outlets to the Red River, or by installing pumps. It is estimated that any of these projects could be done for about $500,000 and should be started after significant stage lowerings on the Red River have been achieved, i.e., about 2030.

s. Sulphur River Basin, Texas-Arkansas.

(1) Streams above Texarkana Reservoir. An estimated 110,000 acres of bottom lands along the Sulphur River and its principal tributaries will receive a high degree of protection from the authorized Cooper Reservoir and Channels, Texas, project. Protection along the North Sulphur River valley is afforded by local channel improvements accomplished in the 1920's. Residual flood problems along the upper reaches of Middle and South Sulphur Rivers, White Oak Creek, and other tributaries exist on about 85,000 acres, of which 40,000 acres are cleared. These cleared areas have a high frequency of flooding, ranging from one to five times per year, and are composed of soils capable of a medium level productivity.

Losses to crops, pastures, and livestock constitute the bulk of flood damages suffered, followed by relatively minor losses to the local road systems. Adequate flood control would permit the conversion of the woodlands to pasture and/or croplands. Allowing for natural swamp areas and other lands unsuitable for

agricultural development by 2080, an estimated 25,000 acres, in addition to the 40,000 acres presently cleared, will require flood damage protection. Numerous reservoir plans to reduce overall basin flooding were considered, but all proved to be economically infeasible. Attempts also were made to formulate local protection projects to solve the flood control problems. Existing channel improvements on the North and South Sulphur Rivers have caused serious channel erosion which has damaged roads, bridges, and cropland. Extensive repair and reconstruction work has been required. Consequently, any further channel enlargements would have to be properly safeguarded by erosion control measures.

Various methods to prevent erosion were studied, all of which proved to be so expensive as to preclude development of feasible channel enlargement plans. Loop levees also were considered but the elongated configuration of the flood plain requires levees of excessive length in terms of the area inclosed. None of the plans considered by the Corps of Engineers produced annual benefits in excess of the annual costs involved, although studies made by the U. S. Department of Agriculture indicate that 78 floodwater retarding and multiple-purpose structures in the upstream areas are economically feasible. A system of this type appears to be the most practical means of providing flood control for the areas of the basin above Lake Texarkana.

(2) Days Creek (Texarkana), Texas-Arkansas. This stream serves as the drainage outlet for the cities of Texarkana, Texas, and Arkansas. Under present conditions, urban lands in the lower limits of the cities of Texarkana, and rural lands downstream from the cities totaling 5,700 acres are subject to periodic flooding and consequent damage. Days Creek serves as the only outlet for storm runoff. Five tributary creeks, Howard, Wagner, Cowhorn, Swampoodle, and Nix collect city runoff and empty into Days Creek. These creeks are crossed at more than 50 locations by streets, railroads and various utilities, many of which provide restricted opening for flood flows. The problem has been aggravated by increased runoff produced by the growth of the urban area. City population has increased 73 percent between 1940 and 1960 and is expected to double between 1960 and 1990.

Present urban flood damages are in excess of $65,000 annually. A plan has been developed that will eliminate these damages and provide additional land suitable for industrial, commercial, and residential use. The plan consists of the enlargement of Days Creek to provide an adequate outlet for the cities' drainage system, as well as extensive improvement of the drainage system itself. Studies show this plan to be economically justified. The project would have a first cost, including drainage improvements within the cities, of $5,580,000; annual costs of $252,000; and annual benefits of $270,300. These improvements, in conjunction with proper management and regulation of the flood plain to prevent development in unsuitable areas, will provide for the orderly future growth of Texarkana. Details of the plan are contained in appendix XV, "Plan Formulation."

t. <u>Posten Bayou, Arkansas-Louisiana</u>. Posten Bayou is a left bank tributary of the Red River and flows for its entire length through the alluvial bottoms of that stream. This area is subject to headwater flooding as well as backwater flooding from the Red River. Problems of inundation from Red River overflow in Arkansas have been eliminated by a system of Federal flood control reservoirs and a local protection levee. However, in the lower reaches an area of some 8,000 acres, 5,000 of which are cleared, are subject to flooding due to backwater from Red River. (This acreage is included in the totals shown for the Red River Main Stem.)

About 16,000 acres (12,500 cleared) in Arkansas are subject to headwater flooding. Under present conditions, floodwaters pond above the Louisiana State line for periods up to 2 weeks. Resulting damages of $87,000 annually are primarily agricultural, comprised of losses to crops, pastures, and livestock. Despite existing problems, considerable land clearing has been taking place over the past few years. The lands lying within the fertile Red River alluvial bottoms would be readily convertible to higher utilization with adequate flood control and drainage improvements. Headwater flood control protection will be needed on about 15,250 acres in Arkansas for peak productivity in this area by 2080. This would allow for clearing 2,750 acres in addition to the existing 12,500 cleared acres.

A combined Corps of Engineers and Soil Conservation Service plan for these 15,250 acres will have a first cost of $2,503,000 and will produce annual benefits of $388,500 at an annual cost of $164,000. Detailed data on this plan are contained in the interim report, "Posten Bayou, Arkansas," dated March 1968, prepared by the U. S. Army Engineer District, New Orleans, and in appendix XV, "Plan Formulation."

Backwater stages in lower Posten Bayou will decrease when the flow line of the Red River is lowered. At that time, various plans could be developed to provide additional protection to the area. Enlarged outlets, pumping facilities, headwater retarding structures, and a diversion channel into Louisiana all are considered as possible future improvements. An expenditure of about $500,000 in about 2030 is considered adequate to provide the required protection.

u. <u>Cypress Creek Basin, Texas-Arkansas-Louisiana</u>. This watershed covers approximately 3,520 square miles. Runoff from about 850 square miles of the drainage area is controlled by the Ferrells Bridge Dam (Lake O' the Pines) on Cypress Bayou. Downstream of the dam, Black Cypress and Little Cypress Creeks join Cypress Bayou before it enters Caddo Lake. James Bayou, another major tributary, drains directly into Caddo Lake. Discharges from Caddo Lake are joined by flows from Black Bayou and are conveyed via Twelvemile Bayou to the Red River at Shreveport, Louisiana. Flood control needs along individual streams in the basin are given below.

(1) Kelly-Black Bayous, Texas-Arkansas-Louisiana. The flood plain from Louisiana State Highway 170 to a point approximately 2 miles north of the Arkansas-Louisiana state line comprises 12,200 acres, of which 8,600 acres are cleared lands. About 90 percent of this area is comprised of fertile, alluvial, Red River bottom land. Major flooding occurs only during periods of intense rainfall and can be expected at rather infrequent intervals; normal rainfalls are accommodated by an adequate outlet with connecting laterals. Flooding from Red River is prevented by existing Federal and local works. Primary flood damages are to agriculture and livestock; minor losses are sustained by the local road system and through the rerouting of traffic. As the bottom lands along Red River are among the most productive in this region, it is anticipated that future needs for agricultural production will require a maximum output in the Kelly Bayou Basin. Allowing for areas unsuitable for future agricultural production, it is estimated that by 2080 about 9,500 acres will need additional flood damage protection. This area comprises 8,600 acres of presently cleared lands and some 900 acres of lands expected to be cleared by 2080. Current average annual damages are estimated at $24,000.

Of the four flood control plans studied, enlargement of the existing channel of Kelly Bayou or construction of the authorized Black Bayou Reservoir were found to offer the best means for alleviating the flood problem. Discussions with the Soil Conservation Service indicated that no increased land utilization benefits would accrue to the improvements. The flood prevention benefits for either plan do not approach the annual costs, and neither is, therefore, economically justified.

Possible improvements to provide flood protection that will be needed over the 100-year study period include enlargement of the bayou, diversion channels to decrease flows in the bayou, or construction of the authorized Black Bayou Reservoir. It is estimated that these improvements will be justified by the year 2020. The most economical plan could be constructed for about $1 million.

(2) Frazier Creek, Texas. The maximum area subject to flooding along the length of this stream is estimated to be 16,000 acres, of which 1,500 are cleared. The watershed is mainly hilly upland country, with bottom lands varying up to 3 miles in width, heavily wooded, and traversed by a winding channel overgrown with trees and brush. Soils have relatively poor agricultural potential. Floods cover a large portion of the creek bottom lands about three times annually. Minor agricultural losses result to cattle and pasture grasses. Other improvements suffering damages are small oilfield facilities, and one railway, as well as county and local roads. Because of the flooding problems and low soil fertility,

little agricultural development exists within the overflow plain. Therefore, the flood control needs for Frazier Creek, considering the small amount of land conversion likely to occur, are estimated to total about 2,500 acres by year 2080, an increase of 1,000 acres over existing conditions.

The only practicable solution to the flood problem along Frazier Creek is channel improvement. Various size channels were designed and the benefits therefrom determined. The average annual damages under existing conditions are about $5,000, essentially all of which could be prevented by enlargement of Frazier Creek. In addition, the enlargement would result in increased land utilization valued at about $37,000 per year, for a total annual benefit of about $42,000. The annual cost for the proposed improvements, however, is over $100,000. The plan, therefore, is not economically justified.

(3) Black Cypress Creek, Texas. This stream flows through hilly upland country with mostly wooded bottom lands. The area subject to overflow consists of approximately 6,000 acres, of which 400 are cleared lands used primarily for pasture. The lower reaches of the basin are subject to frequent flooding and have not been developed. Flood damages are sustained by local roads and bridges with attendant losses due to disruption of travel. Oilfield operations experience some interruptions due to flooding of entry roads and machinery. Agricultural losses include damage to or destruction of farm equipment, structures, and crops. There are also minor cattle losses.

Because of low soil fertility and the lack of local interest in agricultural production in this area, future flood control needs will be nominal. An estimated 1,000 acres, including the 400 acres of presently cleared land, will need protection by the year 2080.

Annual flood damages are $6,500 with $2,100 attributable to crop losses and $4,400 to oilfield operations and local roads. Channel improvement plans were devised to provide varying degrees of protection. Besides flood protection, all of the plans would produce land enhancement benefits. Of all the plans studied, one to provide protection from a 3-year frequency flood was found to be the most practicable. Even this plan was not economically justified, however, since it produced annual benefits of only $21,000, while its annual cost was over $34,000.

(4) Cypress Bayou, Texas. This stream is tortuous, unimproved, and overgrown in many locations by trees, saplings, and underbrush. Most of the cleared land is utilized for pasture. The area subject to overflow from the record flood lies between Texas Highways 37 and 11 and aggregates about 13,500 acres, of which 4,000 are cleared and 9,500 are wooded. Approximately 8,000 acres (2,500

cleared) are located above the proposed Titus County Dam near U. S. Highway 271. The remaining 5,500 acres (1,500 cleared) are downstream of the damsite. Considerable overflow during periods of medium or heavy rainfall cause flood damages of about $6,000 annually. Flood damages are sustained by local roads and bridges, and travel is disrupted during inundation periods. Agricultural losses are due to reduced or destroyed crop stands and pasture and, in some cases, loss of grazing time. Other losses include the cost of moving livestock to higher areas and losses from cattle drownings.

Because of the history of flooding in the area, only a small percentage of the flood plain has been utilized for agricultural purposes. Other factors retarding agricultural development include exorbitant costs for woodland clearing and draining and the predominance of poor soil types with low agricultural potential. Furthermore, most of the existing cropland parcels are not of sufficient size to be conducive to large scale mechanized farming. Access is limited by the presence of many natural channels, sloughs, and depressed areas. Because of these undesirable features and despite an ever increasing demand for overall food production, it is believed that only 3,200 acres or about 30 percent of the available woodland will be converted to agricultural use by year 2080. Therefore, the anticipated total (2080) needs for flood damage reduction amount to 7,200 acres, which includes the 4,000 presently cleared acres, plus 3,200 acres of anticipated future development.

The major feature of the plan found to be most practical is a pilot channel. Natural erosion would enlarge this small channel to the desired ultimate cross section. This plan would eliminate about 80 percent of the present flood damages and would make possible the conversion of some 3,200 acres of woodland. Benefits accruing to the plan amount to $48,000 annually, consisting of about $5,000 of flood prevention and $43,000 of land enhancement. The annual cost of the plan is $187,000; therefore, economic justification is clearly lacking.

(5) Little Cypress Creek, Texas. The area subject to overflow from the maximum record flood extends from the head of Little Cypress Creek near the U. S. Highway 71 crossing to the vicinity of the Louisiana and Arkansas Railway crossing at Jefferson, Texas. The affected area covers 31,000 acres, 6,500 of which are cleared. Most of the cleared land is in pasture. The streambed is tortuous in nature, and in many places overgrown by small trees, saplings, and underbrush. Medium or heavy rainfall causes considerable overflow with annual damages amounting to about $21,000. Floods damage local roads and bridges and cause losses in agricultural production. All of the 6,500 acres of cleared land require some additional flood protection. Because of the flood threat, only a small percentage of the flood plain has been utilized for agricultural purposes. It is estimated that about 40 percent

(8,000 acres) of the available woodland will be converted to agricultural use by the year 2080.

A plan was developed that would eliminate about 80 percent of these damages and in addition provide about $96,000 of land enhancement benefits on some 12,800 acres. The plan consists mainly of enlarging the existing channel of Little Cypress Creek. Although total annual benefits of this plan are $114,000, the annual cost of $200,000 prohibits implementation of the plan at this time.

(6) Twelvemile Bayou (Upper Caddo Levee District), Louisiana. There are approximately 9,400 acres (3,600 cleared) subject to flooding due to ponding of interior runoff during periods of high stages in Twelvemile Bayou. The problem derives both from headwater flood flows which originate in the Cypress Creek Basin above the junction of Black Bayou and from high backwater stages from the Red River. Floodgates which normally drain leveed areas may be closed for extended periods, ponding considerable interior drainage runoff. Damages within the Upper Caddo Levee loop amounting to about $10,000 per year are primarily agricultural with additional losses being sustained by residences, farm buildings, and the local road system. Oilfield operations experience some interruptions due to flooding of access roads and, in some cases, machinery and equipment are damaged. Additional flood protection is needed on all of the presently cleared lands.

Several factors indicate that the need for flood protection will increase in the future. The affected area is near the city of Shreveport, Louisiana, and urban development toward this watershed is anticipated. Furthermore, the land is fertile and topographically favorable to development. Because of the desirable characteristics of this area, about 3,500 acres, or 60 percent, of the available woodland will probably be cleared and converted to other uses by year 2080. Therefore, anticipated needs for flood damage reduction equal the present 3,600 cleared acres plus the anticipated clearing of 3,500 acres or a total of 7,100 acres.

The only practicable solution to the ponding problem would be pumping facilities to evacuate the impounded runoff. The cost of installing and operating the pumps is high and economic justification at this time is clearly lacking. However, at a later date, when lowering of stages on Red River has been accomplished by the authorized plan, pumping facilities to evacuate headwater runoff would be a practical method of flood relief. The cost of these pumping facilities, which should be economically justified around 2050, would be about $2,500,000. This project is, therefore, included in the long-range plan of development.

Other studies were made to determine the justification for improving a levee along the east bank of the bayou just above Shreveport, Louisiana (West Agurs Levee). It was found that

strengthening this levee to provide a higher degree of protection would provide annual benefits of $170,000 at a first cost of $282,000, with an annual cost of only $13,000. Details of these studies are shown in appendix XV, "Plan Formulation."

Incorporation of a non-Federally constructed levee along Twelvemile Bayou into the Federal levee system has been requested by local interests. Based on available information, costly modifications would be required to bring this levee to Federal standards, and based on current estimates, the expenditures would not be justified. The levee has withstood several major floods, however, and continuing consideration should be given to the possibility of incorporating it into the Federal system.

(7) Middle Bayou and McCain Creek, Louisiana. Flooding in this basin results from headwater flows in Middle Bayou and McCain Creek, together with backwater from Twelvemile Bayou and Red River. Lands subject to overflow encompass an area of some 3,000 acres within the Red River alluvial flood plain. About 1,500 acres of this area are cleared. Open lands in this basin are partially used for native pasture. During periods of flooding, roads, bridges, and oilfield machinery are damaged, oilfield operations are interrupted, and agricultural losses are incurred. It is anticipated that by 2080, the city of Shreveport will have expanded to include all of this area. Therefore, the total future need for flood protection includes all lands in the basin or 3,000 acres. Channel improvements by local interests in the upper reach have been effective in lowering flood heights and reducing flood duration to a few hours. Recent field investigations indicate that flood losses are small and are confined to the native pastures that lie within the very narrow overflow limits adjacent to the stream. Economic justification for additional improvements in this upper area was lacking, primarily because of the shape of the flooded area (long and narrow), and the inordinate length of levee required for each acre protected. It is unlikely that flood control improvements for this upper area will ever become economically justified. However, it is likely that some residential developments will take place in the area; in fact, pressure for such development is already in evidence. It would appear that the negative prognosis for the development of economically feasible flood control improvements in the area should be recognized in long-range planning, and that appropriate consideration should be given to conforming future development to this reality.

In the lower reaches of the basin economic justification for levee construction is marginal at this time. It appears that protection will, however, be economically justified in the reasonably near future. An early request for detailed, independent consideration of this area under section 205 of the Flood Control Act of 1962, as amended, is anticipated.

v. Brush Bayou, Louisiana. Two flood control projects have been constructed along this stream which serves as a drainage outlet for a portion of the city of Shreveport, Louisiana. Studies made for this report indicate that continued expansion of the city will support further improvement in the future, and a channel improvement project with a cost of $100,000 has been included in the long-range plan. Additional information which has become available only recently indicates that the need for this project may develop within the early-action time frame. It is anticipated that studies will be initiated at an early date under the continuing authority of Section 205 of the Flood Control Act of 1962, as amended, to determine whether construction should be undertaken within the next 10-15 years.

w. Loggy Bayou Basin, Arkansas-Louisiana.

(1) Bayou Bodcau, Red Chute Bayou, Flat River system, Arkansas-Louisiana. Upon completion of a presently authorized flood control system in this basin, an estimated 46,000 acres will remain subject to periodic inundation and will suffer average annual flood losses of about $12,000. Of this 46,000 acres, about 33,000 (8,000 cleared), primarily in the upper reaches, will be exposed to infrequent headwater inundation while nearly 13,000 acres (6,000 cleared) will be flooded occasionally by backwater from Red River.

Lands within the basin are composed of Red River alluvial bottom land which are fertile and highly productive. Development of the basin, until now, has been hampered by flood and drainage problems. By 2080, additional protection from backwater flooding will be needed on about 8,000 acres. This need is included in those shown on the Red River Main Stem. Protection from headwater flooding will be needed on the 8,000 acres of presently cleared land, plus 5,000 acres of anticipated woodland conversion.

Numerous plans of improvement were developed to reduce the average annual flood damages that will remain when the presently authorized project is constructed. Improvement of Loggy Bayou, a levee along Red Chute Bayou and Flat River, and reservoirs were studied but in no case did the benefits approach the costs. No flood control improvements, therefore, are recommended for this area at this time.

Two areas in this basin appear to be particularly well suited for further development and require additional flood protection. One area is along Flat River in the vicinity of Bossier City, Louisiana. By about 2020, urban development will have progressed to the point where additional local drainage and pumping facilities will be required. Possible alternatives include channel improvement and upstream floodwater retarding structures. About $500,000 is considered adequate to cover the cost of whatever plan is chosen.

The other area likely for development is below the confluence of Bayou Bodcau and Loggy Bayou. This land is highly fertile and should be brought into production as soon as works to reduce stages on the Red River have been initiated. The most logical plan of protection appears to be a loop levee on the west side of Loggy Bayou. This work will cost about $1,500,000 and will probably be economically justified by about the year 2005.

(2) Bayou Dorcheat, Arkansas-Louisiana. The flood plain of Bayou Dorcheat in Arkansas and Louisiana above the Lake Bistineau Dam aggregates some 52,000 acres, including 1,700 acres of open land, 2,200 acres of gravel pits, 1,800 acres of wooded campsites, and 8,500 acres of oilfield lands. As the greatest part of the bottoms is relatively flat and drained only by a small, overgrown channel, flooding is experienced several times each year. Improvements subject to damage include strip gravel mining operations, oilfield operations, homes, camps and other buildings around the edge of Lake Bistineau, local roads, and highway and railroad crossings. Average annual damages amount to about $34,000.

Due to the excessive frequency and duration of flooding, very little of the Bayou Dorcheat bottom land has been devoted to agricultural production. Other factors tending to retard development include the inaccessibility of much of the area, excessive moisture-holding characteristics of the soils, the high cost of woodland conversions and attendant drainage installations, and the marginal productive capabilities of the soils. Despite an ever-increasing demand for overall food production, it is believed that because of these adverse conditions only some 2,500 additional acres, or about 5 percent of the available woodland, will be converted to agricultural use by year 2080. Therefore, total future needs in the Bayou Dorcheat Basin, including the existing flood control need of 14,200 acres, are estimated to be 16,700 acres.

Improvement of the channel of Bayou Dorcheat was investigated, but the benefits resulting from this plan were minor compared to its cost. A levee along Bayou Dorcheat was studied, but the benefits it would produce, though significant, were not of sufficient magnitude to justify its construction. Single- and multiple-purpose reservoir plans also were developed. The cost of single-purpose flood control reservoirs, or the inclusion of flood control storage in multiple-purpose reservoirs, was far greater than the benefits such reservoirs would produce.

x. Bayou Nicholas (Coushatta), Louisiana. Bayou Nicholas drains an area of approximately 5 1/2 square miles, including the town of Coushatta. About 300 acres of alluvial bottom land in and adjacent to the town are protected from Red River overflow by a levee system and floodgate. Under present conditions, average annual flood losses resulting from ponding of rainfall during high stages

on Red River are negligible. As some croplands adjoining urban areas will probably be converted to residential or commercial use during the study period (1980-2080), better flood protection may be needed for some of the area. An estimated 200 acres will eventually require interior drainage improvements.

y. Campti-Clarence Area, Louisiana. A Federal flood control project was recently completed in this area. The project, consisting of a ring levee and floodgate system, will protect some 29,500 acres (20,000 cleared) of alluvial bottom lands from Red River overflow. Of this total, about 6,100 acres (1,000 cleared) will be subject to infrequent flooding by ponded runoff during periods when high stages on the Red River necessitate the closing of the floodgates. Included within the area subject to residual flooding (6,100 acres) are some 2,700 acres (1,000 cleared) along Bayou Bourbeaux which remain exposed to relatively minor headwater overflow losses.

The alluvial bottoms in this basin are highly productive and readily lend themselves to higher utilization. Maximization of agricultural output will require the installation of additional flood control works for protection on the 1,000 presently cleared acres, plus 2,000 acres of anticipated woodland conversions.

With the authorized flood control improvements in place, remaining flood damages will be only about $500 annually. Construction of two pumping plants would eliminate these damages and provide about $10,000 of increased land utilization benefits. Since the annual cost of installation and operation is about five times the average annual benefits, the plan is not economically justified at this time. By about 2020, estimated increases in agricultural development of this area will make necessary a higher degree of flood protection, and the project is included in the long-range plan of development.

z. Cane River-Kisatchie Bayou, Louisiana. The flood plain of some 38,000 acres (18,000 cleared) includes most of the lands lying west of Cane River between the towns of Natchez and Galbraith in Louisiana. This area is inundated by headwater overflow from rainstorms in the hills of the Kisatchie National Forest and by rather infrequent backwater flooding from high stages on Red River. In the latter instances, the area has remained flooded for as long as 2 months. Damages of about $52,000 are sustained annually. Existing Federal and local flood control works have materially reduced overflow problems caused by Red River; however, headwater flooding in both streams remains a problem.

Because of the excessive frequency and duration of flooding, agricultural damages have been extensive, with losses to crops, pasture, and livestock. Some damage is done to farm buildings, houses, small commercial establishments, highways, local roads, one railroad, and utilities. Agricultural development of the area has been drastically reduced and expansion has been kept to a minimum.

As part of the fertile Red River alluvial bottoms, this land is readily adaptable for conversion to higher utilization uses from existing woodland and unimproved pasture as evidenced in a nearby protected area, where extensive land clearing has taken place over the past few years. Additional flood control is needed on the 18,000 acres of presently cleared lands and will be needed on an additional estimated 8,500 acres by 2080.

Several methods for satisfying the flood control needs were considered. These included channel enlargement, levees, channel clearing and snagging, and single- and multiple-purpose reservoirs. Only the multiple-purpose reservoir which, in addition to storage for flood control, contains storage for irrigation and water supply, was found to be economically justified. The project would have a total first cost of $20,500,000. Annual costs would be $1,321,100, and annual benefits would be $2,694,000, of which $502,000 would be for flood control. Details of this reservoir plan are contained in appendix XV, "Plan Formulation."

Drainage improvements on Cane River Island were investigated and found to lack economic justification. It is estimated that by about 2015, the installation of pumps to evacuate the impounded runoff will become economically justified and such a project is included in the basin long-range plan of development.

aa. Bayou Rapides (Rapides Island), Louisiana. Drainage on Rapides Island is effected by two means: a floodgate and pumping station located at the bayou's entry into Red River and a relief floodgate which permits excess flows to be diverted into the Bayou Cocodrie system on some occasions. Use of the relief floodgate, however, is subordinate to the needs of the Bayou Cocodrie system, and in most storms, the gate must be closed. The presently installed pump, when used as the only means of evacuating ponded overflows, is of insufficient capacity to prevent damaging floods. Some 16,000 acres (10,000 cleared) are subject to inundation when stages on Red River preclude the operation of the gravity outlet. A major portion of this area is used primarily for agricultural purposes. England Air Force Base is located in the area, and the city of Alexandria has expanded on to the eastern end of the island with residential, commercial, and industrial improvements.

Protection from Red River overflows is afforded by a levee along the main stem.

Since soils are very fertile and high crop yields are attainable, large tracts of woodland have been cleared in the last decade. The area is adjacent to the city of Alexandria and is already experiencing suburban development. Because of the potential for higher utilization of this area (both urban and agricultural), it is estimated that all of the area will need additional flood control and drainage works by year 2080.

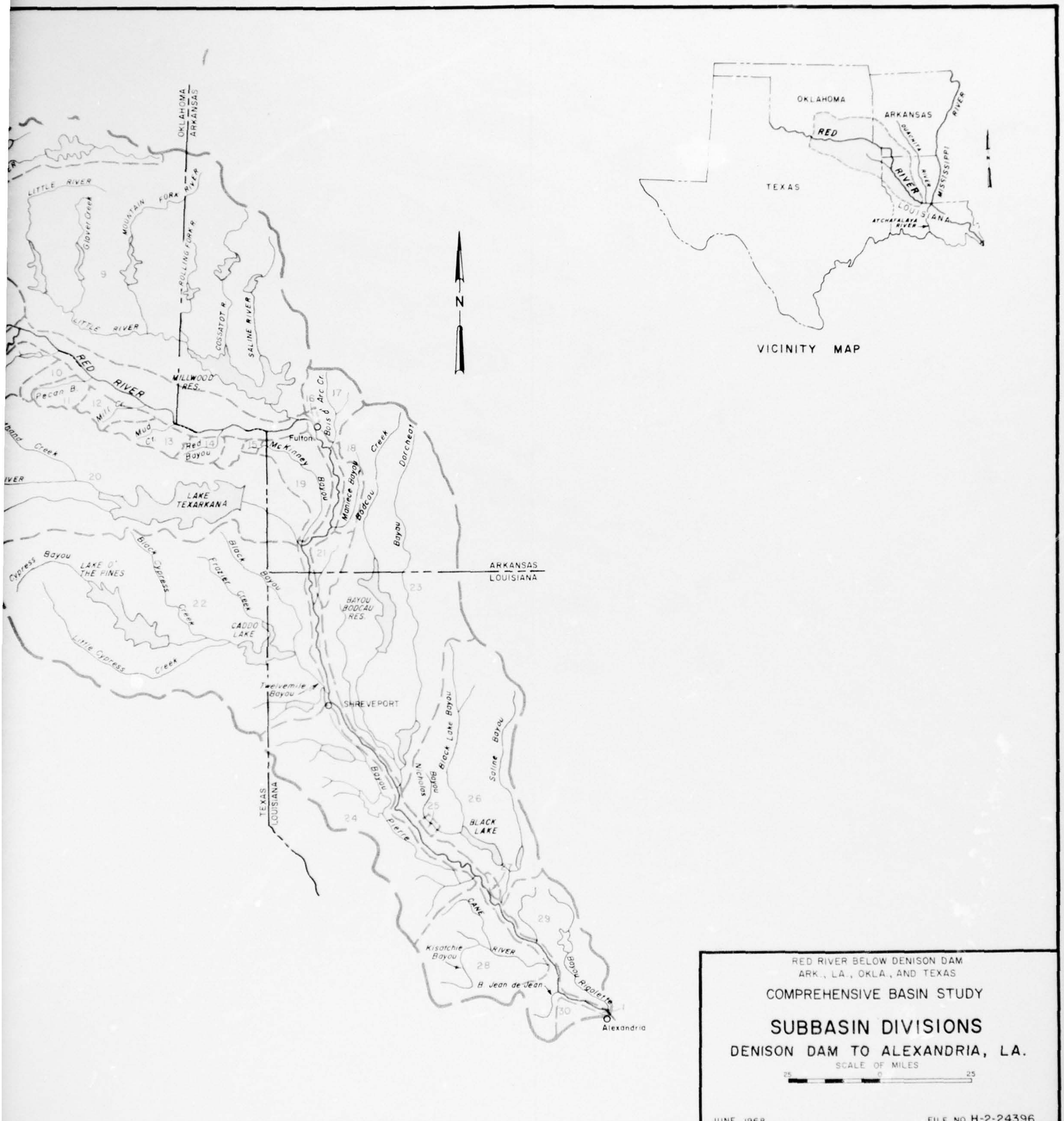
The only effective method to eliminate the flooding is the installation of pumps to convey the water into the Red River when existing outlets are inoperative. Installation of the pumping facilities is not economically justified at this time but will become feasible by about 2005. The cost of such an installation is estimated to be $750,000.

bb. Bayous Du Grappe-Rigolette, Louisiana. Approximately 16,000 acres of cleared land in this basin currently require additional flood protection. By 2080, this need is expected to increase to 25,000 acres. The Soil Conservation Service has developed a plan that will relieve flooding in this area. For details of the plan, see appendix V, "Upstream Watershed Protection, Use, Management, and Development."

11. FLOOD PLAIN INFORMATION REPORTS

There are scattered urban areas in the basin where flood plain information reports would be helpful to local agencies in establishing preventive measures that could result in limiting certain flood damages. The Corps of Engineers, upon request, assists State agencies and local governments throughout the nation by preparing flood plain information reports outlining flood conditions, and providing technical assistance in use of the data.

AREA NO.	SUBBASIN	AREA NO	SUBBASIN
1	Red River, Main Stem	16	Hempstead Levee District No. 1
2	Choctaw Creek	17	Bois d'Arc Creek
3	Brown Creek	18	Manieve Bayou
4	Island Bayou	19	McKinney Bayou
5	Blue River	20	Sulphur River
6	Bois d'Arc Creek	21	Posten Bayou
7	Boggy Creek	22	Cypress Bayou
8	Kiamichi River	23	Loggy Bayou
9	Little River & Tributaries	24	Bayou Pierre
10	Colliers Creek	25	Bayou Nicholas
11	Pecan Bayou	26	Black Lake - Saline Bayou
12	Mill & N. Mill Creeks	27	Campti-Clarence
13	Mud Creek	28	Cane River - Kisatchie Bayou
14	Red Bayou	29	Bayou DuDrappe - Rigolette
15	Barkman Creek	30	Bayou Rapides



RED RIVER BELOW DENISON DAM
ARK., LA., OKLA., AND TEXAS

COMPREHENSIVE BASIN STUDY

SUBBASIN DIVISIONS

DENISON DAM TO ALEXANDRIA, LA.

SCALE OF MILES

25 0 25

JUNE 1968 FILE NO. H-2-24396

APPENDIX IV PLATE I